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ectronic Business

FOR MANAGEMENT IN ELECTRONICS, COMPUTER & SYSTEMS COMPANIES — WORLDWIDE SEPTEMBER 1, 1988

POWER OF ATTORNEY

How Intel holds on to its technology assets PAGE 30

Beating the high cost of test PAGE 112

Sensors star in car wars PAGE 102

Thomas Dunlap
Intel's executive vice president and general counsel

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Electronic Business

FOR MANAGEMENT IN ELECTRONICS, COMPUTER AND SYSTEMS COMPANIES—WORLDWIDE

VOL. 14, NO. 17 SEPTEMBER 1, 1988

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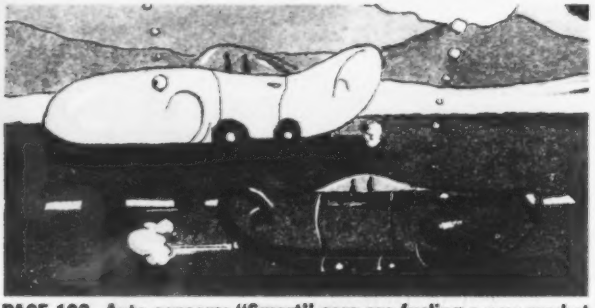

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ELECTRONIC BUSINESS articles are available on a custom printing basis at reasonable prices. Contact Joanne Westphal, Cahners Reprint Service, Cahners Plaza, 1350 E. Touhy Ave., P.O. Box 5080, Des Plaines, Ill. 60018 (312) 635-8800
Total Circulation: 76,550

Don't tread on them

To more than a few executives in this business, Intel is becoming the company they love to hate. The haters feel that way because they happen to be targeted by the chip giant as it fights to keep what it holds dearest: its intellectual property.

Electronics companies spend more than many to foster technology, and the last thing they want is to see it ripped off. That's why patents, copyrights and trademarks have become more important than ever, and why, in the last year or so, acrimonious legal battles for custody of a particular invention or process have raged, at immense cost to all involved. Just look at some of the big lawsuits now running: Apple versus Hewlett-Packard; Intel versus NEC. So we decided to take a serious look at the extent of the problem and at the way some of the big guys handle it.

Intel handles it with an aggressive "don't tread on me" attitude, as associate editor Valerie Rice ably explains in her cover story. The same goes for DEC, whose feisty stance has put several smaller companies off their strategic stride.

Are DEC and Intel only doing what's right to protect what's theirs? Or are they using bullying legal tactics that do the industry at large little good? And is a month or two spent preparing for courtroom battles really a productive way to spend your marketing vice president's time? Read on — and don't miss the 12-point guide to intellectual-property protection in our next issue.

Associate editor Valerie Rice

This week's special is . . .

Their promoters would hate to hear us call them gadgetry, but what else do you call the little electronic gizmos that you may soon see on supermarket shelves? Our story on the emergence of digital shelf labels, which update this week's price of your favorite breakfast cereal by remote, caters to a very human fascination with gadgets — and points to potentially huge buys of low-cost LCDs and microprocessors. Spare a thought, though, for all the bored 5-year-olds soon to be deprived of the joy of sliding the plastic labels every which way.

JOHN KERR

ELECTRONIC BUSINESS® (ISSN 0163-6197) is published semi-monthly, except monthly in December, by The Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Terrence M. McDermott, President; Frank Sibley, Group Vice President; Jerry D. Neth, Vice President/Publishing Operations; J.J. Walsh, Financial Vice President/Magazine Division; Thomas J. Dellamaria, Vice President/Production and Manufacturing. Circulation records are maintained at Cahners Publishing Company, 44 Cook Street, Denver, CO 80206-5800. Telephone: (303)388-4511. Second-class postage paid at Denver, CO 80206-5800 and additional mailing offices. POSTMASTER: Send address corrections to ELECTRONIC BUSINESS® at the Denver address. ELECTRONIC BUSINESS® copyright 1988 by Reed Publishing USA; Saul Goldweitz, Chairman; Ronald G. Segel, President/C.E.O.; Robert L. Krakoff, Executive Vice President; William M. Platt, Senior Vice President. Annual subscription rates for non-qualified people: USA/Canada/Mexico, $55 per year; other countries, $85 per year (including air freight). $170 per year for air mail. Except for special issues where price changes are indicated, single copies of regular issues are available for $6.00, $8.00 and $10.00 (USA, Canada/Mexico *and foreign*). *Please address all subscription mail to Eric Schmierer,* 44 Cook Street, Denver, CO 80206-5800. Cahners Publishing Company, A Division of Reed Publishing USA • Specialized Business Magazines for Building & Construction • Manufacturing • Foodservice & Lodging • Electronics & Computers • Interior Design • Printing • Publishing • Industrial Research & Technology • Health Care • Entertainment. Specialized Consumer Magazines: American Baby • Modern Bride.

BPA ABP

Education and liberty

I just finished reading Frank Burge's "My View" titled, "Education: The safeguard of liberty" in your July 1 issue and I was horrified [by the story of a worker who couldn't communicate well enough to do her job].

My greatest concerns are the drug probem and the basic educational system of the U.S. I believe that the educational system can help attack the drug problem, so it is very important.

Young people come out of the educational system (through high school) with a very poor general education. It is hard to compete in the world markets with the Japanese when you don't know what Japan is or even where it is.

It doesn't matter whom we blame, but I agree that action is required. By the way, I blame the parents who don't care enough about their own children's education. The same school systems that are turning out functional illiterates also turn out extremely well educated Chinese, Vietnamese and Cuban children. The difference is that the parents have respect for education. In fact, the parents have a passion for education.

Amaury Piedra
President and Chief Executive Officer
Seattle Silicon Corp.
Bellevue, Wash.

CAE wins with licensing

Your CAE software article in the June 1 issue was a good summary of why software and hardware are still bundled together in the CAE business. But I think that the sidebar doesn't do justice to network licensing. Someone probably dismissed the first Intel Corp. microprocessor, the 4004, as "just a collection of transistors." I think that you may be doing the same thing by calling network license software just "creative software pricing 101."

Valid Logic Systems Inc.'s access product follows on the heels of Apollo Computer Inc.'s Network License Server and Digital Equipment Corp.'s License Management Facility. In a recent study of network licensing, we identified more than 20 other vendors who will offer "floating" software as an alternative to CPU-locked software before yearend. Network licensing will be a major factor in deciding who wins and loses in the battle for the corporate purse. It allows companies to license software in a flexible way that better matches their needs. Firms can at last share infrequently used, expensive software across an unprecedented number of users.

Network licensing will increase CAE penetration. Improved design quality and manufacturing productivity are the likely results. Network licensing may lead to creative pricing and interesting negotiations. But the real winners will be the CAE vendors and their customers who use network licensing of software as a strategic technology.

James H. Geisman
President
Marketshare Inc.
Wayland, Mass.

Corrections

In the May 1 issue of ELECTRONIC BUSINESS, we misidentified the appropriate contact at the Hong Kong Government Industrial Promotion Office. Donald M. Fletcher is now the principal consultant at the group's San Francisco office.

We inadvertently left Weiss, Peck & Greer off our May 15 listing of top venture capital companies. Robert J. Loarie is the contact at the Palo Alto, Calif., firm that has nearly $170 million in venture capital funds. Also omitted was The Vista Group, a New Canaan, Conn., firm with $203 million in capital. Gerald B. Bay is the contact.

In our June 1 ranking of the most profitable companies, we neglected to include Network Systems Corp. From 1982 to 1987, Network Systems posted an average 33.5% growth per year. The Minneapolis-based firm makes and sells datacommunications systems that interconnect computers from most major manufacturers.

And, due to an error in filmmaking, the chart accompanying our August 1 story on Hewlett-Packard was unintelligible. The chart is reproduced correctly on this page.

Letters to the editor

ELECTRONIC BUSINESS welcomes letters to the editor on any topic of interest to our readers. If not written on organizational letterhead, all letters must include a telephone number. ELECTRONIC BUSINESS reserves the right to edit letters.
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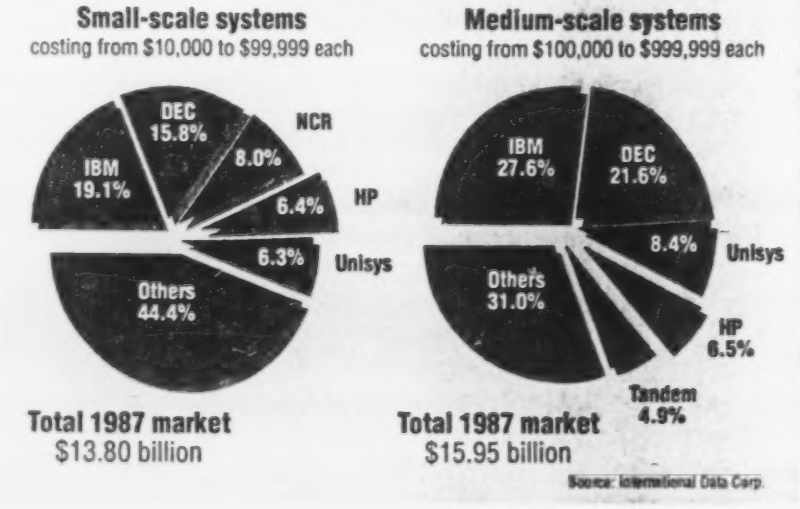
HP's share of the 1987 worldwide computer market

Value of shipments of U.S. vendors worldwide



The top R&D spenders in the electronics industry

R&D spending was up last year for the third straight year, as companies continue to accelerate their technology investments

BY DWIGHT B. DAVIS and LINDA STALLMANN

Led by the software, capital equipment and minicomputer sectors, 100 of the top U.S. electronics firms pumped 8.6% of their sales revenue into research and development during 1987. Cullinet Software Inc. paced the pack, devoting more than a quarter (28.5%) of its $174.9 million in revenue to R&D. Last year's leader, Advanced Micro Devices Inc., dropped to second place, with 24.9% of its $997.1 million in sales so committed.

Actual R&D expenditures at the 100 companies jumped from $13.0 billion in 1986 to $15.8 billion last year, a whopping 21.5% increase. This leap came despite a more modest 12.6% growth in sales, which climbed from $162.1 billion to $182.5 billion over the same period.

Driving the industry's continuing commitment to R&D have been a combination of factors, including foreign competition, increasing technological complexity and short product life cycles. "The rate of creation of new products is very high in the electronics industry," notes Todd Hixon, vice president of the Boston Consulting Group. "As a result, these companies have to spend continuously on research and development."

This analysis is seconded by Austin Mayer, director of investor relations at Sun Microsystems Inc., which ranked 14th in percentage of revenue devoted to R&D. "Our products typically have an 18 to 24 month life cycle, which means that we're constantly replacing our line," Mayer says. "We always have several generations of products under development simultaneously, which takes a lot of money and effort."

As a subset of the overall economy, electronics far surpasses most other industry sectors in its percentage of revenue spent on R&D. U.S. companies overall devoted only 3.4% of their 1987 sales revenue to R&D, according to *Business Week* magazine, or less than half the percentage of the electronics firms.

"The pure play electronics companies such as the big CPU vendors and the semiconductor firms are very committed to research and development," says analyst Hixon. "Many of the big industrial companies, on the other hand — even firms such as General Electric, that have electronics divisions — have come to the conclusion that it's better to take advantage of horizontal mergers with other companies than to invest a lot in R&D." (To qualify for the ELECTRONIC BUSINESS R&D ranking, companies must derive at least 70% of their revenue from electronics-related sales and be included in the ELECTRONIC BUSINESS 200.)

Still, 1987 shortfalls in sales accounted for at least some of the high percentage of revenue spent at the top-ranked firms. Once R&D budgets are set and projects begun, it can be difficult to cut them back quickly, even if anticipated revenue doesn't materialize. Year-end figures may then reflect unexpectedly high percentages of revenue devoted to R&D.

AMD, for example, had planned to cut its 1987 R&D spending to about 20% of revenue, but softer than expected sales kept the percentage in the mid-20s. For 1988, however, the company is on track in its attempt to hold such spending at 20% of revenue, having cut back on some programs, such as SRAM development, and eliminated other projects entirely.

Even so, 20% spending represents far more than the industry norm, even within the relatively high-spending semiconductor sector, which devoted 9.5% of its 1987 sales to R&D. "Semiconductor companies are pursuing a technology that is not yet close to its limits," explains Hixon.

Foreign competition also plays an important role in this sector, according to AMD chairman and CEO W. Jerry Sanders III. "The U.S. microelectronics industry is in a crucial struggle to retain parity in semiconductor manufacturing with foreign competitors," he said recently, when announcing plans for a new manufacturing facility. "State-of-the-art research and development facilities are essential as the semiconductor industry moves rapidly into the submicron era."

In addition, U.S. chip makers have been forced into large R&D outlays as the lower ends of their product lines have achieved commodity

status, according to Hixon. "As the Asian companies continue to take share in the commodity end of the market, the U.S. firms must look for advances in application-specific and other high-end products."

Nevertheless, at least two factors have worked to keep semiconductor R&D spending under control. The industry's average R&D expenditures dropped from 10.6% in 1986 to 9.5% last year, in part because industry-wide sales were extremely strong in 1987, despite softness in some industry segments. The monies earmarked for R&D last year therefore ended up accounting for a smaller percentage of overall revenue.

This trend may continue in 1988, says Bob Reed, chief financial officer at 12th-ranked Intel Corp. "We're having another good year," he says, "so it's possible that the percentage of revenue spent on R&D may drop, even though we will show a healthy increase in absolute spending." Intel will spend at least $300 million this year on R&D, Reed predicts, up from $260 million last year. "The key is to keep absolute spending growing at a steady pace," he maintains.

The second factor working to ease R&D costs in the semiconductor sector is the proliferation of design automation systems and other productivity tools, according to Reed. Such products "have been a phenomenal help in holding down costs," he says. Without the consequent boost in research productivity, Reed estimates that Intel would have spent $350 million to $400 million on R&D last year, not $260 million, to achieve the same results.

Closely linked to the semiconductor sector are the capital equipment companies, many of which produce the machines and processes used to fabricate and test memory and microprocessor chips. These firms spent an average of 11.2% of revenue on R&D in 1987, placing them second only to the high-spending software segment. Applied Materials Inc., ranked at No. 4, spent well above the capital equipment industry average last year, with 17.9% of its revenue going toward R&D, but chairman and CEO James C. Morgan expects his company to approach the sector norm in coming years.

R&D spending at top electronics companies increased 21.5% despite a more modest 12.6% growth in sales

"During the industry downturn we spent very heavily on new products in the etcher, ion implant, epitaxy and CVD [chemical vapor deposition] areas," he explains. "We're now spending on technology at a run rate of about $40 million a year, and in actual dollars we expect to spend more every year. But as a percentage of sales, we expect R&D to decline to about 10% to 12%, assuming we're spending $35 million or more in absolute dollars. The nature of our business is such that if you spend something in that order of magnitude you can get a lot accomplished."

Of Applied Materials' 1,700 worldwide employees, over 200 are directly involved in research and development, Morgan says. A corporate committee of key technology executives is responsible for reviewing product development, although Morgan ultimately oversees all technology projects. "We have about three pages of things I'd like to get to," he says, "and we review the list every six months." Morgan also notes that the company works closely with its customers, "so we can leverage our R&D in that way."

However, neither the semiconductor sector nor the capital equipment companies can match the software industry when it comes to percentage of sales spent on R&D. Software firms spent a whopping 12.4% of their 1987 revenue on R&D, up from 10.1% in 1986. Some of this rise came at the expense of earnings at some of the software companies.

First-ranked Cullinet, for example, suffered a loss of $27.6 million in 1987, caused in part by the company's large commitment to R&D spending. Cullinet devoted $50 million to R&D in 1987, up from $35.5

Leaders in R&D spending

Total 1987 R&D expenditures ($ millions)

1	IBM	$5,434.0
2	Digital Equipment	1,010.4
3	Hewlett-Packard	901.0
4	Xerox	722.0
5	Unisys	597.0
6	Motorola	524.0
7	Texas Instruments	428.0
8	GM Hughes Electronics	416.0
9	Control Data	389.0
10	NCR	356.6
11	Honeywell	289.8
12	Intel	259.8
13	Advanced Micro Devices	247.8
14	National Semiconductor	218.9
15	Wang Laboratories	212.4

1987 R&D expenditures per employee

1	Apple Computer	$34,206
2	Lotus Development	27,819
3	Cray Research	25,262
4	Amdahl	23,545
5	VLSI Technology	22,698
6	Ashton-Tate	22,388
7	Applied Materials	22,193
8	Microsoft	20,967
9	Cullinet Software	20,723
10	Mentor Graphics	20,149
11	LTX	19,919
12	Digital Communications	17,775
13	Altos Computer Systems	17,646
14	3Com	16,837
15	Sun Microsystems	16,637

1987 R&D expenditures as a percentage of revenue

1	Cullinet Software	28.5%
2	Advanced Micro Devices	24.9%
3	LTX	19.2%
4	Applied Materials	17.9%
5	VLSI Technology	17.8%
6	Teradyne	16.3%
7	Cray Research	15.8%
8	Analog Devices	15.1%
9	Lotus Development	14.8%
10	Tektronix	14.3%
11	Computer Consoles	14.0%
12	Intel	13.6%
13	GenRad	13.6%
14	DSC Communications	13.1%
15	Computer Associates	13.0%

Fiscal 1987 figures

Source: ELECTRONIC BUSINESS

million the previous year. "The increase was done by intent, even though we knew it would depress our earnings," says Jeff Papous, vice president for corporate marketing.

Cullinet needed to commit additional funds to R&D, Papous explains, because the company had acquired several companies in an attempt to broaden its product line beyond the IBM mainframe marketplace. "The acquisitions accelerated our time to market," he says, "but we needed to beef up our internal R&D to make all of the new products compatible with one another and with our existing line."

Papous says Cullinet is also spending heavily in R&D because of the firm's efforts to develop applications software to supplement its traditional systems software products. Nevertheless, the company's percentage of R&D spending will drop to about 19% of revenue this year, and should hold steady at that level, he says.

Although Cullinet experienced unique pressures in 1987 that pushed its R&D spending percentage above all other electronics companies, several shared aspects of the software industry worked to keep the sector as a whole at the top of the R&D list. "In a way, software companies are almost pure product development businesses," says analyst Hixon. "Their raw materials and manufacturing costs are negligible compared to other industry sectors, and the percentage of money spent on R&D is subsequently higher."

The company profile at ninth-ranked Lotus Development Corp. supports this perspective, given that approximately one-third of the firm's employees have some R&D association, according to Ed Belove, vice president for corporate R&D. But an unrelated factor is probably responsible for the software sector's 2.3% jump in spending from 1986 to 1987, he believes.

Platform proliferation

"From 1981 to 1986, many of us in the software industry had a single platform on which to build our products: the IBM PC and its compatibles," Belove notes. "Around 1986, however, all sorts of new platforms appeared, including OS/2 and Presentation Manager-based machines, Unix workstations, the Macintosh and, for us, mainframes. During 1987, we undertook a lot of efforts to develop products for these different platforms, and our expenses, subsequently, were high."

Companies with the fastest growth in R&D spending

R&D expenditures	Percentage growth from 1986	Total 1987 ($ millions)
Genicom	143.3%	$14.9
MiniScribe	131.7%	19.8
Sun Microsystems	127.0%	69.6
Maxtor	98.3%	11.8
Micropolis	94.5%	21.8
3Com	86.7%	9.3
Microsoft	85.5%	38.1
Lotus Development	79.6%	58.4
Compaq Computer	77.1%	47.1
Intelligent Systems	70.2%	6.5
BBN	65.4%	14.3
Computer Associates	58.1%	40.1
Wyse Technology	55.6%	13.9
Western Digital	51.6%	37.4
Amdahl	50.2%	178.9

Source: ELECTRONIC BUSINESS

Lotus' 14.8% R&D spending in 1987 was "probably a bit high for us," says Belove. The company doesn't set specific spending goals for R&D as a percentage of revenue, but Belove believes 10% would be closer to the desirable level. Still, he expects that this year's spending may continue at an elevated rate, in part because customers want compatibility among all the different types of machines now installed. Achieving such compatibility will require continued heavy R&D investments, Belove predicts.

Software firms don't yet have the productivity tools to keep costs down

In addition, software companies don't yet have the productivity tools that have helped the semiconductor industry hold its costs down, points out Martyn Roetter, manager of the information and telecommunications industry practice at Arthur D. Little. "CASE [computer-aided software engineering] tools have not yet fulfilled their promise," he says. "As a result, software development is still very people-intensive."

Other electronics industry sectors, such as the peripherals, communications, components and government groups, fall below the 8.6% industry spending average, but even the lowest ranked (5.4%) government sector surpasses the 3.4% average of all U.S. businesses. The reasons why these sectors trail others in the electronics industry are varied. In the case of the defense-dependent government sector, for example, reductions in DOD expenditures have kept R&D spending down.

In other cases, subcategories of companies within sectors have bucked their sectors' overall trends. One example is that of disk drive companies within the peripherals sector. Three of the top five companies ranked by the percentage increase in revenue spent on R&D from 1986 to 1987 were disk drive manufacturers.

This jump reflects the "law of diminishing returns" in this sector, says Robert Katzive, vice president of Disk/Trend Inc. "You can spend the same amount and be late in the marketplace, or you can spend more and keep up," the market researcher says. "And this industry isn't kind to latecomers."

Technological factors have also put pressure on disk drive companies to increase sales, Katzive says, with low-end vendors shifting to the small format 3.5-inch drives and high-end suppliers packing more capacity into their products. "Drives in the 380-megabyte and above range are not easy to design [or manufacture]," he notes.

In the future, it can be expected that electronics companies of all types will continue to outpace other industry sectors in R&D outlays.

"Looking at the total R&D expenditure is too crude a measure," Roetter says. "How much is spent on basic research? How much on design engineering? How much on product engineering?" he asks.

Noting the success that Japanese firms have achieved by concentrating resources on manufacturing engineering, Roetter believes that U.S. firms need to follow suit. "It makes no sense to spend lots of money developing advanced new products if there's no way to economically manufacture them," he concludes.

Top R&D spenders

1987 R&D rank	Company	R&D as a percentage of revenue	Total R&D expenditures ($ millions)	Percentage change in expenditures from 1986	Fiscal 1987 revenue ($ millions)	Percentage change in revenue from 1986	Fiscal 1987 net income ($ millions)	Percentage change in net income from 1986	Fiscal year ended
1	Cullinet	28.5%	$49.9	40.4%	$174.9	-7.6%	-$27.6	NM	4/87
2	Advanced Micro Devices	24.9%	247.8	34.8%	997.1	73.1%	-48.1	NM	12/87
3	LTX	19.2%	23.2	7.5%	120.6	26.4%	-6.7	NM	7/87
4	Applied Materials	17.9%	31.2	26.7%	174.4	16.9%	0.3	-72.9%	10/87
5	VLSI Technology	17.8%	30.5	31.0%	172.0	54.0%	8.1	14,294.6%	12/87
6	Teradyne	16.3%	61.5	21.1%	377.7	23.4%	-21.5	NM	12/87
7	Cray Research	15.8%	108.8	24.1%	687.3	15.2%	147.1	17.8%	12/87
8	Analog Devices	15.1%	56.0	23.8%	370.4	10.8%	18.7	-20.2%	10/87
9	Lotus Development	14.8%	58.4	79.6%	395.6	39.9%	72.0	49.2%	12/87
10	Tektronix	14.3%	199.6	0.7%	1,395.9	2.8%	51.2	30.2%	5/87
11	Computer Consoles	14.0%	20.8	-13.3%	148.4	14.5%	9.6	NM	12/87
12	Intel	13.6%	259.8	13.8%	1,907.1	50.8%	175.5	NM	12/87
13	GenRad	13.6%	26.4	-26.6%	193.8	-5.2%	2.1	NM	12/87
14	DSC Communications	13.1%	40.9	-11.5%	312.4	2.8%	14.6	31.9%	12/87
15	Computer Associates	13.0%	40.1	58.1%	309.3	31.9%	36.5	96.9%	3/87
16	Sun Microsystems	12.9%	69.6	127.0%	537.5	155.8%	36.3	203.8%	6/87
17	General DataComm	12.6%	25.3	29.2%	200.6	12.7%	0.8	-80.1%	9/87
18	Data General	12.5%	159.4	11.4%	1,274.3	0.5%	-82.9	NM	9/87
19	Avantek	12.3%	26.3	3.5%	213.7	2.6%	11.6	-28.0%	12/87
20	Amdahl	11.9%	178.9	50.2%	1,505.2	55.8%	142.0	261.0%	12/87
21	National Semiconductor	11.7%	218.9	-1.6%	1,867.9	26.4%	-28.8	NM	5/87
22	Digital Communications	11.6%	21.1	35.3%	181.4	31.6%	27.0	31.2%	6/87
23	Control Data	11.6%	389.0	23.9%	3,366.5	0.6%	25.0	NM	12/87
24	Prime Computer	11.4%	109.7	19.3%	960.9	11.7%	64.8	38.0%	12/87
25	Micom Systems	11.3%	22.3	40.2%	196.7	3.8%	12.2	13.2%	3/87
26	Coherent	11.3%	18.0	21.4%	159.0	15.1%	-1.1	NM	9/87
27	Cipher Data Products	11.3%	20.1	33.3%	178.2	9.3%	4.3	-39.8%	6/87
28	Hewlett-Packard	11.1%	901.0	9.3%	8,090.0	13.9%	644.0	24.8%	10/87
29	Apollo Computer	11.0%	61.1	36.9%	553.7	41.4%	21.7	132.5%	12/87
30	LSI Logic	11.0%	28.9	34.1%	262.1	34.9%	10.7	178.8%	12/87
31	Microsoft	11.0%	38.1	85.5%	345.9	75.1%	71.9	83.1%	6/87
32	Mentor Graphics	10.9%	24.2	43.9%	221.8	27.9%	20.3	84.8%	12/87
33	Fluke	10.8%	22.2	-7.8%	206.3	-1.5%	2.0	-83.5%	9/87
34	Digital Equipment	10.8%	1,010.4	24.1%	9,389.4	23.7%	1,137.4	84.2%	6/87
35	Intergraph	10.5%	67.5	16.9%	641.1	5.8%	69.9	-0.7%	12/87
36	Perkin-Elmer	10.5%	140.2	33.5%	1,333.6	3.3%	-18.2	NM	7/87
37	Tandem Computers	10.5%	108.5	25.2%	1,035.5	34.9%	105.6	65.6%	9/87
38	Ashton-Tate	10.5%	28.0	43.5%	267.3	26.8%	43.1	43.1%	1/88
39	Stratus Computer	10.3%	18.9	34.0%	184.2	47.8%	19.4	43.5%	12/87
40	Gould	10.1%	94.3	-3.7%	933.4	2.7%	25.0	-27.7%	12/87
41	IBM	10.0%	5,434.0	36.7%	54,217.0	5.8%	5,258.0	9.8%	12/87
42	Westmark International	9.6%	28.0	17.9%	291.9	19.8%	-7.2	NM	12/87
43	Quantum	9.5%	11.5	1.8%	120.8	-0.4%	8.8	-60.4%	3/87
44	ADC Telecommunications	9.3%	15.5	19.2%	166.9	16.1%	15.3	27.5%	10/87
45	Applied Magnetics	9.2%	19.5	14.9%	211.9	65.4%	14.2	246.6%	9/87
46	Dynatech	9.0%	27.3	23.7%	304.7	18.7%	23.2	13.5%	3/87
47	Altos Computer Systems	9.0%	13.8	27.9%	153.9	14.7%	9.7	-52.3%	6/87
48	AMP	8.8%	204.0	20.0%	2,317.8	19.9%	249.7	51.9%	12/87
49	TIE/communications	8.6%	21.4	-6.2%	250.2	-16.1%	-11.1	NM	12/87
50	3Com	8.4%	9.3	86.7%	110.4	72.5%	11.1	66.8%	5/87

NM = Not meaningful. The company lost money in the base year

(Continued)

Top R&D spenders

1987 R&D rank	Company	R&D as a percentage of revenue	Total R&D expenditures ($ millions)	Percentage change in expenditures from 1986	Fiscal 1987 revenue ($ millions)	Percentage change in revenue from 1986	Fiscal 1987 net income ($ millions)	Percentage change in net income from 1986	Fiscal year ended
51	Medtronic	8.4%	$42.1	9.3%	$502.0	24.6%	$73.8	9.5%	4/87
52	ISC Systems	8.4%	14.1	-5.2%	168.5	1.5%	6.5	-52.9%	6/87
53	Varian Associates	8.2%	80.7	-1.9%	982.8	10.3%	21.4	NM	9/87
54	Paradyne	8.2%	19.0	-2.4%	232.6	-10.9%	-2.6	NM	12/87
55	Western Digital	8.1%	37.4	51.6%	462.5	65.5%	42.8	99.2%	6/87
56	Storage Technology	8.0%	60.1	-3.3%	750.0	7.8%	19.0	12.8%	12/87
57	Motorola	7.8%	524.0	6.5%	6,707.0	13.9%	308.0	58.8%	12/87
58	Texas Instruments	7.7%	428.0	5.4%	5,594.5	12.5%	256.9	543.9%	12/87
59	Micropolis	7.5%	21.8	94.5%	288.3	35.2%	27.2	49.3%	12/87
60	Wang Laboratories	7.5%	212.4	4.7%	2,836.7	7.3%	70.7	38.9%	6/87
61	Gerber Scientific	7.4%	16.6	-7.2%	223.9	16.7%	21.1	15.8%	4/87
62	Measurex	7.3%	16.7	18.3%	227.4	18.0%	26.8	27.3%	11/87
63	Apple Computer	7.2%	191.6	49.9%	2,661.1	39.9%	217.5	451.7%	9/87
64	Xerox	7.0%	722.0	11.1%	10,320.0	10.3%	578.0	18.4%	12/87
65	Diasonics	6.9%	18.5	35.4%	267.6	23.2%	15.2	NM	12/87
66	Aydin	6.7%	10.0	32.4%	149.2	9.1%	8.8	26.6%	12/87
67	Maxtor	6.7%	11.8	98.3%	175.3	105.9%	22.4	109.5%	3/87
68	Dataproducts	6.6%	22.4	-27.9%	338.8	-4.3%	9.0	NM	3/87
69	Watkins-Johnson	6.4%	16.9	4.2%	264.3	3.5%	17.1	-0.7%	12/87
70	NCR	6.3%	356.6	11.2%	5,640.7	15.5%	419.3	24.6%	12/87
71	Veeco Instruments	6.2%	12.2	-1.4%	195.6	16.6%	9.2	2,328.2%	9/87
72	Datapoint	6.2%	19.4	-14.4%	312.1	-4.0%	-58.5	NM	7/87
73	Unisys	6.1%	597.0	35.4%	9,712.9	30.7%	578.0	NM	12/87
74	Bolt Beranek and Newman	6.1%	14.3	65.4%	233.8	31.3%	-8.0	NM	6/87
75	Oracle Systems	6.0%	7.9	12.9%	131.3	137.0%	15.6	165.0%	5/87
76	Cherry Electrical Products	6.0%	9.6	11.1%	160.6	24.2%	2.7	NM	2/87
77	Harris	5.7%	118.0	0.1%	2,079.0	-6.2%	84.5	41.8%	6/87
78	Decision Industries[1]	5.7%	10.9	6.4%	191.4	-1.9%	-20.4	NM	11/87
79	M/A-COM	5.6%	24.5	-28.0%	436.1	-24.5%	-29.3	NM	9/87
80	Molex	5.5%	21.2	23.6%	386.8	32.5%	43.4	35.5%	6/87
81	MiniScribe	5.5%	19.8	131.7%	362.5	96.0%	28.1	38.8%	12/87
82	AST Research	5.4%	11.1	32.1%	206.0	19.5%	13.0	-52.0%	6/87
83	Wyse Technology	5.3%	13.9	55.6%	260.0	56.2%	18.1	44.1%	3/87
84	International Rectifier	5.3%	8.1	-12.5%	151.8	4.6%	-17.2	NM	6/87
85	Augat	5.1%	16.1	-3.6%	313.2	20.4%	11.5	NM	12/87
86	Genicom	4.9%	14.9	143.3%	302.2	91.9%	12.6	45.9%	12/87
87	Sprague Technologies	4.8%	20.8	-6.7%	437.3	-2.6%	3.6	NM	12/87
88	Litton Industries	4.7%	209.7	-18.3%	4,419.7	-2.2%	138.1	94.3%	7/87
89	Kollmorgen	4.7%	14.2	-14.6%	301.0	-5.7%	0.3	NM	12/87
90	Andrew	4.7%	10.4	-21.7%	223.2	12.9%	3.8	-59.9%	9/87
91	Esterline	4.7%	12.1	6.1%	259.7	10.1%	-29.3	NM	10/87
92	Loral	4.6%	32.0	3.3%	690.0	4.0%	57.5	8.4%	3/87
93	Recognition Equipment	4.4%	11.6	0.3%	264.7	9.5%	11.2	6.4%	10/87
94	Zenith Electronics	4.4%	103.4	3.7%	2,362.7	24.9%	-19.1	NM	12/87
95	Honeywell	4.3%	289.8	17.5%	6,679.3	24.2%	253.7	1,866.7%	12/87
96	Scientific-Atlanta	4.1%	20.1	-27.1%	495.3	5.6%	24.3	NM	6/87
97	MAI Basic Four	4.0%	12.9	-16.0%	321.0	14.2%	22.8	34.9%	9/87
98	Intelligent Systems	4.0%	6.5	70.2%	163.2	30.0%	10.2	540.6%	12/87
99	GM Hughes Electronics	4.0%	416.0	1.9%	10,481.0	0.4%	521.1	17.1%	12/87
100	Compaq Computer	3.8%	47.1	77.1%	1,224.1	95.8%	136.3	217.7%	12/87

NM = Not meaningful. The company lost money in the base year
[1] Decision Industries went private April 29, 1988

Source: ELECTRONIC BUSINESS

Top R&D spenders by industry segment

Fiscal 1987 figures

Minicomputers

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
IBM	$5,434.0	10.0%	$13,957
Digital Equipment	$1,010.4	10.8%	$9,144
Hewlett-Packard	$901.0	11.1%	$10,988
Data General	$159.4	12.5%	$10,163
Prime Computer	$109.7	11.4%	$12,439
Tandem Computers	$108.5	10.5%	$15,481
Gould	$94.3	10.1%	$9,313
Sun Microsystems	$69.6	12.9%	$16,637
Apollo Computer	$61.1	11.0%	$15,285
Computer Consoles	$20.8	14.0%	$16,144
Stratus Computer	$18.9	10.3%	$15,449
MAI Basic Four	$12.9	4.0%	$3,960
Segment total	**$8,000.7**	—	—
Segment averages	—	**10.3%**	**$12,551**

Mainframes

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
IBM	$5,434.0	10.0%	$13,957
Unisys	$597.0	6.1%	$6,454
Control Data	$389.0	11.6%	$11,275
NCR	$356.6	6.3%	$5,752
Amdahl	$178.9	11.9%	$23,545
Cray Research	$108.8	15.8%	$25,262
Segment total	**$7,064.4**	—	—
Segment averages	—	**9.4%**	**$11,968**

Office equipment

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
IBM	$5,434.0	10.0%	$13,957
Xerox	$722.0	7.0%	$7,293
NCR	$356.6	6.3%	$5,752
Wang Laboratories	$212.4	7.5%	$7,009
Harris	$118.0	5.7%	$4,856
Pitney Bowes	$65.1	2.9%	$2,210
Datapoint	$19.4	6.2%	$7,046
Diebold	$14.3	3.3%	$2,938
Savin	$4.6	1.3%	$2,272
Segment total	**$6,946.4**	—	—
Segment averages	—	**8.9%**	**$10,785**

Microcomputers

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
IBM	$5,434.0	10.0%	$13,957
Apple Computer	$191.6	7.2%	$34,206
Zenith Electronics	$103.4	4.4%	$2,954
Compaq Computer	$47.1	3.8%	$11,776
Atari	$18.0	3.7%	$4,412
Altos Computer	$13.8	9.0%	$17,646
AST Research	$11.1	5.4%	$8,186
Tandon	$10.3	3.6%	$2,938
Segment total	**$5,829.3**	—	—
Segment averages	—	**9.5%**	**$13,138**

Government

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
Motorola	$524.0	7.8%	$5,363
Texas Instruments	$428.0	7.7%	$5,488
GM Hughes Electronics	$416.0	4.0%	$4,160
Honeywell	$289.8	4.3%	$3,674
Litton Industries	$209.7	4.7%	$3,869
Harris	$118.0	5.7%	$4,856
Gould	$94.3	10.1%	$9,313
Varian Associates	$80.7	8.2%	$6,784
Singer	$38.4	2.0%	$1,371
E-Systems	$33.7	2.7%	$2,173
Loral	$32.0	4.6%	$2,203
Watkins-Johnson	$16.9	6.4%	$5,414
Aydin	$10.0	6.7%	$5,023
Cubic	$5.2	1.4%	$1,164
Logicon	$1.6	0.8%	$643
Segment total	**$2,298.4**	—	—
Segment averages	—	**5.4%**	**$4,376**

Semiconductors

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
Motorola	$524.0	7.8%	$5,363
Texas Instruments	$428.0	7.7%	$5,488
Intel	$259.8	13.6%	$13,531
Advanced Micro Devices	$247.8	24.9%	$13,755
National Semiconductor	$218.9	11.7%	$7,497
Harris	$118.0	5.7%	$4,856
Gould	$94.3	10.1%	$9,313
Analog Devices	$56.0	15.1%	$10,777
Western Digital	$37.4	8.1%	$11,204
VLSI Technology	$30.5	17.8%	$22,698
LSI Logic	$28.9	11.0%	$12,465
International Rectifier	$8.1	5.3%	$3,429
Segment total	**$2,051.7**	—	—
Segment averages	—	**9.5%**	**$7,049**

Capital equipment

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
Hewlett-Packard	$901.0	11.1%	$10,988
Tektronix	$199.6	14.3%	$11,676
Perkin-Elmer	$140.2	10.5%	$9,929
Varian Associates	$80.7	8.2%	$6,784
Teradyne	$61.5	16.3%	$13,089
Applied Materials	$31.2	17.9%	$22,193
GenRad	$26.4	13.6%	$12,484
LTX	$23.2	19.2%	$19,919
John Fluke	$22.2	10.8%	$9,258
Gerber Scientific	$16.6	7.4%	$9,229
Esterline	$12.1	4.7%	$3,834
Sun Electric	$5.0	2.4%	$2,035
Segment total	**$1,519.7**	—	—
Segment averages	—	**11.2%**	**$10,532**

(Continued)

Top R&D spenders by industry segment

Fiscal 1987 figures	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
Computer-based systems			
Hewlett-Packard	$901.0	11.1%	$10,988
Honeywell	$289.8	4.3%	$3,674
Intergraph	$67.5	10.5%	$10,710
Coherent	$18.0	11.3%	$11,106
Measurex	$16.7	7.3%	$6,578
Gerber Scientific	$16.6	7.4%	$9,229
ISC Systems	$14.1	8.4%	$7,898
Recognition Equipment	$11.6	4.4%	$3,990
Sun Electric	$5.0	2.4%	$2,035
Segment total	**$1,340.3**	—	—
Segment averages	—	**8.0%**	**$7,434**
Communications			
Motorola	$524.0	7.8%	$5,363
DSC Communications	$40.9	13.1%	$16,076
Dynatech	$27.3	9.0%	$8,818
Avantek	$26.3	12.3%	$8,651
General DataComm	$25.3	12.6%	$9,574
General Instrument	$24.7	3.1%	$1,517
M/A-COM	$24.5	5.6%	$3,624
Micom Systems	$22.3	11.3%	$10,924
TIE/communications	$21.4	8.6%	$14,298
Digital Communications	$21.1	11.6%	$17,775
Scientific-Atlanta	$20.1	4.1%	$5,999
Paradyne	$19.0	8.2%	$6,095
ADC Telecommunications	$15.5	9.3%	$8,615
Bolt Beranek and Newman	$14.3	6.1%	$5,352
Andrew	$10.4	4.7%	$4,528
Aydin	$10.0	6.7%	$5,023
3Com	$9.3	8.4%	$16,837
Dynascan	$1.6	0.8%	$4,145
Segment total	**$858.0**	—	—
Segment averages	—	**7.5%**	**$5,609**
Peripherals			
Control Data	$389.0	11.6%	$11,275
Storage Technology	$60.1	8.0%	$6,776
Seagate Technology	$33.6	3.5%	$2,097
Dataproducts	$22.4	6.6%	$5,731
Micropolis	$21.8	7.5%	$9,124
Cipher Data Products	$20.1	11.3%	$10,683
MiniScribe	$19.8	5.5%	$3,988
Applied Magnetics	$19.5	9.2%	$2,807
Genicom	$14.9	4.9%	$4,163
Wyse Technology	$13.9	5.3%	$6,863
Maxtor	$11.8	6.7%	$6,109

Continued next column

	Total R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D expenditures per employee
Peripherals (continued)			
Xidex	$11.6	2.0%	$1,679
Quantum	$11.5	9.5%	$16,522
Decision Industries	$10.9	5.7%	$7,027
Tandon	$10.3	3.6%	$2,938
Intelligent Systems	$6.5	4.0%	$13,235
Segment total	**$688.6**	—	—
Segment averages	—	**7.9%**	**$6,786**
Components			
AMP	$204.0	8.8%	$9,273
Molex	$21.2	5.5%	$4,264
Sprague Technologies	$20.8	4.8%	$2,414
Augat	$16.1	5.1%	$4,237
Cherry Electrical	$9.6	6.0%	$3,333
AVX	$8.4	3.1%	$1,120
CTS	$5.3	2.0%	$798
BRIntec	$4.5	1.5%	$1,152
Oak Industries	$4.0	2.2%	$1,046
Segment total	**$293.9**	—	—
Segment averages	—	**6.4%**	**$4,581**
Software			
Lotus Development	$58.4	14.8%	$27,819
Cullinet Software	$49.9	28.5%	$20,723
Computer Associates	$40.1	13.0%	$14,853
Microsoft	$38.1	11.0%	$20,967
Ashton-Tate	$28.0	10.5%	$22,388
Mentor Graphics	$24.2	10.9%	$20,149
Oracle Systems	$7.9	6.0%	$7,026
Ultimate	$4.5	2.6%	$10,000
Segment total	**$251.1**	—	—
Segment averages	—	**12.4%**	**$19,244**
Medical			
Medtronic	$42.1	8.4%	$8,504
Westmark International	$28.0	9.6%	$9,267
Diasonics	$18.5	6.9%	$12,243
Segment total	**$88.6**	—	—
Segment averages	—	**8.3%**	**$9,342**

Segment R&D as a percentage of revenue averages are weighted

Source: ELECTRONIC BUSINESS

Misadventures in AI: What went wrong at Symbolics

Not-so-smart marketing may have downed the Cambridge, Mass., manufacturer of smart machines. Some say a comeback won't be easy

BY ANDREA COHEN

Perched above the receptionist's desk in the lobby of Symbolics Inc. are several pink plastic flamingos. But the frivolous decor is far from indicative of the scrambling going on inside the offices of this Cambridge, Mass., firm.

Industry analysts say the story of Symbolics is a classic case of a technology-driven company which lost — or perhaps never truly found — a suitable marketing direction. The artificial intelligence (AI) pioneer did not foresee the obstacles in transcending its traditional customer base of high-end R&D labs, universities and other more sophisticated users. It was slow in recognizing customers' preferences for software standards such as Unix. And the threat posed by general workstations and personal computers was sorely underestimated.

Indeed, Symbolics is not alone in its misfortunes. One of its hardware competitors, Lisp Machines Inc., declared bankruptcy last year; and other AI software pioneers, such as Intellicorp and Teknowledge Inc., are probably disappointed that the AI software market has not developed as rapidly as some analysts had once predicted. Such difficulties are the result of the AI market's shift from expensive, specialized computers which run AI applications, to software which can be run on the standard computers — personal computers, minis and mainframes — which are already present in many busineses.

The market for high-end users was quickly saturated, leaving the less specialized market open. Such customers, by using more traditional computers, are able to forego the expense of buying specialized hardware and hiring specialized programmers trained to run Lisp, the symbolic-processing language. Thus, the focus has since turned from special purpose hardware to broadbased hardware — traditional workstations like those made by Apollo Computer Inc., Digital Equipment Corp. and Sun Microsystems Inc.

"I don't think anyone realized a couple years ago that at this point you could be approaching the ability to run fairly advanced AI applications, if not development, on even traditional PCs," remarks Symbolics' assistant general counsel, Francis Feeney. The company has made efforts to cut costs and to orient itself around today's AI market needs, but so far without any striking results.

When it was founded in 1980 by engineers and scientists from the Massachusetts Institute of Technology's Artificial Intelligence Laboratory, the company reaped the benefits of its technological excellence in a new technology. Annual revenue climbed from $40.7 million in fiscal 1984 to $69 million in 1985, and all the way up to $114 million in fiscal 1986, ended June 30. And net income rose too: from $1 million in 1984 to nearly $11 million in fiscal 1986.

President Ronald Derry: Down the line, Symbolics' commitment to software and hardware should shift more strongly toward software

Dave Bradley

PC impact

Success evidently went to Symbolics' corporate head. In June of 1986, the company moved from its crowded offices in Cambridge to a new world headquarters among the lush hills and meadows of Concord, Mass., and more employees were hired — just as the AI market began to lose its sparkle.

Six months later, reality set in. To cut costs, Symbolics moved everyone back to the then even more crowded Cambridge location — a move that is perhaps the best watershed in gauging Symbolics' early successes against its difficulties in the past year and a half. Since then, the company has suffered vastly diminished earnings, struggles in upper management, large reductions in workforce, losses and more losses.

For fiscal 1987, income gave way to losses of over $25 million. Recent quarters have shown scant improvement: the three months ended January 3 produced $15.4 million in net losses, with the April quarter closing $4.9 million in the red.

In January of this year, 10% of the company's 730-member workforce was laid off. Then in May, 35% of the remaining staff was bid adieu in order to, as Symbolics' president Ronald L. Derry says, ensure profitability and "to put ourselves in a position where we reduce our costs until a new set of products can hopefully

allow us to expand into new markets."

In February of this year, Derry replaced Brian Sear, who, according to Howard Cannon, a Symbolics cofounder and product director for PC products, "had more of an emphasis on the workstation end of the business, and recently it's become clear that engineering and building our own workstation was not the best way for Symbolics to succeed."

Ill-starred ambition

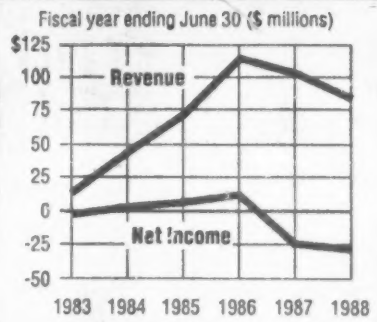
Harvey Newquist, editor of *AI Trends*, a newsletter based in Scottsdale, Ariz., suggests Symbolics may have been overly ambitious. He claims that the company wasn't content being a $100 million a year company and instead "at times felt that it could take on the installed base of normal machines or take on large workstation companies like Sun and Apollo, [which] gave them illusions of grandeur so that they spread into places they really had no business being."

Although most observers agree that the company has never suffered from a lack of technical expertise, such talent has not been adequately matched with marketplace savvy. Feeney says: "When we were growing so quickly here internally, I don't think anybody stopped and said, 'Well, wait a minute, once we saturate that fixed market . . . is there going to be a [broader] market for our system?' "

Feeney adds that Symbolics executives underestimated the problems posed by the fact that although "the sophisticated user has no sort of qualms about getting a different box, a Symbolics box [as opposed to] an IBM or a DEC box," more traditional users are not interested in nonconventional systems.

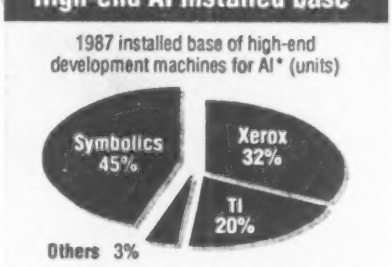
One customer that seems happy with Symbolics, for example, is MCI International, which is using the Symbolics 3620 model to develop an application involving an automated money transfer service. While there are indications that MCI is concerned about the financial stability of Symbolics, it has had no major problems with the machines. Nevertheless, MCI is reportedly evaluating DEC workstations and some PCs based on Intel Corp.'s 80386 and Motorola Inc.'s 68000 series microprocessors to do similar sorts of applications.

Symbolics' sales and income



Sources: Company reports; estimates from Arnhold and S. Bleichroeder Inc.

High-end AI installed base



Total 1987 installed base: 8,000 units

* Excludes internal distribution

Source: Hambrecht & Quist Inc.

Although Symbolics has the highest market share for high-end AI machines, PCs and general workstations have made sizable inroads in the AI field

Symbolics is presently following several routes in order to redefine its market niche. Cofounder Cannon remarks that Symbolics is more interested now in "plugging into those boxes — which other people can build more efficiently — as opposed to building them." One year after its projected shipping date, the company is finally preparing to unveil its Ivory Processor, an embedded package for Apple's Macintosh II machine. The product, due to be shipped by the end of this year, uses Symbolics' Ivory chip, which contains a symbolic processor.

Embarrassingly though, by missing its market window, Symbolics was beaten to the punch by Texas Instruments Inc. In April, TI began shipping its MicroExplorer, a system comprised of a Mac II and a Lisp microprocessor resident on a coprocessor board. Cannon defends Symbolics' late entry, reasoning that TI's model is based on an already existing architecture, whereas Symbolics' version uses a new VLSI implementation.

According to Cannon, Symbolics' R&D labs are particularly working on adding increased capabilities in the form of layered products that customers can add to Genera, Symbolics' operating system software. One product — Statice, an object-oriented database system — has been announced already. Also recently introduced is Cloe (Common Lisp Operating Environment), a layered software package which allows development on a Symbolics system with delivery onto 386-based platforms.

Symbolics is also moving toward more standard hardware. In May, the company announced a deal with Sony Microsystems Co. which enables it to act as a reseller for Sony workstations and as Sony's third-party service arm in the United States. According to Thomas Farb, Symbolics' vice president for finance, this will allow the company's customers the convenience of purchasing Unix workstations from them.

AI market analyst Newquist admits to being "completely baffled" about the agreement. "I think the company is so embedded in its hardware and manufacturing roots that it finds it almost impossible to extricate that from its mindset. I really think that they will not end up keeping the hardware side," he predicts.

However, Farb is adamant: "By no means are we abandoning our hardware." Derry maintains that commitment to software and hardware will be pretty much equal in the immediate future, but down the line, should shift more strongly toward software.

The next year should reveal whether or not Symbolics' staff cuts, product plans and market realignment constitute effective enough damage control. Caution is clearly the watchword in the Symbolics boardroom: executives will not commit openly to a target date for a return to profitability. If things do turn around, those pink flamingos in the lobby may get the last laugh. Otherwise, another model of a bird which hangs from a ceiling in an upper hallway of the Cambridge offices might be a more accurate company mascot. That one's a pterodactyl. □

A detailed look at Japan's AI market

According to a recently published survey, the majority of computer hackers in Japan have already begun trial usage of expert systems

BY SHOHEI KURITA

Artificial intelligence in Japan is slowly, but surely, coming of age. In fact, Japan's demand for AI software will reach $7.7 billion in 1990 and accelerate to $38.4 billion by 1995, predicts a government agency there.

But market figures alone do not tell the whole story. The results from a recent survey conducted by the Japan Information Processing Development Center (JIPDEC) reveal detailed information — published in Japanese last June and translated for ELECTRONIC BUSINESS — about the country's growing AI sophistication. JIPDEC surveyed 1,025 advanced computer users in Japan; 323 companies and organizations responded for a substantial 31.5% reponse rate.

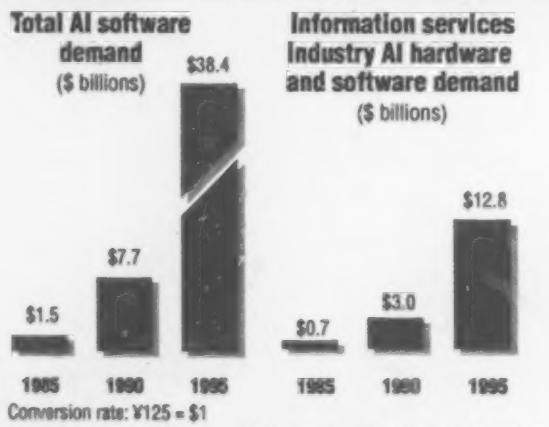
The survey indicates that 55% of Japan's advanced computer users have already begun at least trial usage of an expert system. And nearly 40% indicated that within three years, they would be employing such software for everyday usage. The primary benefit of expert systems — defined as computers with the problem-solving capabilities of human experts — is productivity improvement. For example, Digital Equipment Corp. in Japan uses a number of expert systems in order to streamline the company's operations there [see accompanying story].

The companies surveyed reported that they allocated an average 7% of their entire software development personnel to AI systems development in 1987. Five years later, the companies expect the figure to rise to 21%. The public service related industries — including construction, public utilities, transportation and communications — will be among the leaders in using AI. Companies in such industries expect that 29% of their software personnel will be involved in AI in 1992.

Of the more than 400 expert systems used by the survey's respondents, failure diagnosis was the leading application, with a 31% share. Following that were systems used for planning, 16%; designing, 15%; instruction, 8%; prediction, 6%; data interpretation, 5%; system control, 5%; debugging, 3%; and other miscellaneous applications, 11%. About 59% of all expert systems are used solely in house while 23% are developed with the intent to sell them on the open market. The remaining 18% consists of systems that are developed for in-house usage but which might have a limited market.

According to the survey, Fujitsu Ltd. ranked as the No. 1 vendor of AI "shells," the software framework around which expert systems are written. Almost a quarter of the respondents who use a software shell said they use Fujitsu's ESHELL. The Tokyo-based firm reports that 53% of ESHELL users are manufacturing companies. Universities and research institutes were second in ESHELL us-

Japan's demand for AI

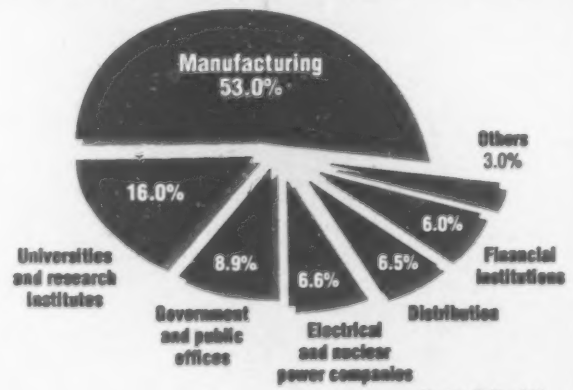


Conversion rate: ¥125 = $1

Source: Institute for New Generation Computer Technology

Who uses AI in Japan?

Survey of Fujitsu ESHELL users (as of October 1987)



Source: Fujitsu Ltd.

age, accounting for 16% of the units sold.

IntelliCorp of Mountain View, Calif., with its Knowledge Engineering Environment (KEE) product, also fared well in the JIPDEC survey. Ten percent of the respondents who had developed their own expert systems said they had done so using KEE.

As far as hardware goes, computers used for expert system development in Japan are comprised of mainframes, 22%; minicomputers, 7%; engineering workstations, 18%; personal computers, 28%; and AI-dedicated machines, 25%. For delivery vehicles used by AI customers, mainframes make up 23%; minicomputers, 6%; workstations, 22%; personal computers, 30%; and 19% by AI-dedicated machines such as the Personal Sequential Inferencecomputer designed by the Institute of New Generation Computer Technology (ICOT). Mitsubishi Electric Corp. sells a licensed commercialized version of the machine.

Hardware from U.S. manufacturers Symbolics Inc. of Cambridge, Mass., and Dallas-based Texas Instruments Inc. also fared well in the survey. In fact, Symbolics has shipped approximately 300 systems thus far in Japan. TI sells its Explorer AI workstations through C. Itoh & Company Ltd.

While expert systems have dominated Japan's AI scene, other applications are currently coming to the fore. The JIPDEC survey indicates that trial usage of image or graphic recognition systems, voice recognition systems, intelligent robots, automatic programming systems and intelligent man-machine interfaces will peak in roughly three years. Real usage of such systems will take five years to reach a plateau, except in the robotic arena, which will take 10 years, reflecting the difficulty of incorporating AI in that field.

Another area of rampant AI activity is in foreign language translation systems, where Japan boasts a worldwide technological lead, according to many industry gurus. The country's Center of the International Cooperation for Computerization — charged by the government to develop a multilingual machine translation system — has sponsored a project involving the governments of China, Indonesia, Malaysia and Thailand.

For the project, Fujitsu, Hitachi Ltd., Mitsubishi Electric, NEC Corp., Oki Electric Industry Company Ltd., Sharp Corp. and Toshiba Corp. are cooperating to develop an intermediate language that will be used to translate Japanese into Chinese, Indonesian, Malay and Thai and vice versa. The Japanese government has allocated roughly $48 million for the project, which should reach completion by 1993. □

Editor's note: an exchange rate of $1 = ¥125 was used.

How DEC puts AI to work in Japan

The following is an excerpt from a speech given by Gen Narui, director of educational services for Nihon Digital Equipment Corp., DEC's Tokyo-based subsidiary. Narui was one of the featured speakers at a seminar on the Japanese electronics industry, cosponsored by the American Electronics Association and ELECTRONIC BUSINESS *and held in Osaka, Japan.*

We use an expert system called Xsel to help our salesmen put together quotations for computer equipment. Our salesmen feed in customer requirements and Xsel determines the most appropriate system. After a salesman writes up a purchase order, we use another expert system, Xcon, to check the order accuracy. Before Xcon was developed, a group of technical editors did this job. They took an average of 30 minutes to check orders and were only about 70% accurate. Now, Xcon makes the checks in two to three minutes and is 98% accurate.

At our factory, we use another expert system, CDS, to determine whether the hardware configuration on the order actually runs. And, in the event that a customer cancels an order, we use a program called Matcher to reassign equipment already in production to other orders. It determines which components must be changed to transform a canceled computer into the configuration a different customer needs.

Our salesmen use an expert system for quoting prices

A program called ND keeps deliveries in line with orders. And another program, Xsite, determines the preparation that must take place at the customer site before new equipment can be installed. And, since many of our computers contain communication devices that feed data into our maintenance centers, we use an expert sytem, AIspear, to anticipate problems at the centers. The program monitors customer data and can predict common problems before equipment actually malfunctions. If equipment does go down, the program tells our engineers what spare parts to take on the repair call.

In Japan, our customers are using expert systems for a variety of purposes. For example, one of the country's largest department stores uses an expert system to streamline its purchasing operations.

Finally, AI can help differentiate products by giving them unique or unusual features. For example, some Japanese word-processing programs stand out from the competition because they incorporate AI. Often, two or more words in Japanese have the same phonetic spelling — as do the English words "hot," meaning very warm, and "hot," meaning spicy. The word processor uses AI techniques to analyze the sentence in question and pick the correct character.

GEN NARUI

Smart sensors play a role in the U.S./Japan auto war

Makers are eyeing a vast new market for "smart" devices that turn "dumb" heaps of metal into intelligent driving machines

BY MICHAEL R. LEIBOWITZ

Dashboards don't look like they used to. Glitzy multicolored arrays instantly alert the driver when something goes wrong. Under the hood, temperature, pressure, speed, flow, position and acceleration are scrupulously monitored. The data is relayed to on-board computers which optimize engine performance.

Sensors make this possible. And now a new generation of devices is turning otherwise "dumb" heaps of metal and components into "smart" cars. Sensors are the eyes, ears and nose of today's vehicles. Sensors first became important for measuring emissions and have spread through the car to keep the brakes from locking, control an auto's suspension and trigger air bags to inflate. In the engine alone, 15 sensors measure everything from manifold pressure to air flow temperature.

Indeed, the dawning of the high-tech automobile has created a veritable gold mine of potential sensor applications and perhaps the biggest opportunity the sensor industry has seen in years. Thank the Japanese for the newfound opportunities. In shaking Detroit out of its competitive slumber, they have created a war that is being fought on slick auto features that require sensors. As a result, the numbers are staggering. Take 33 million cars shipped each year and multiply that by 150 new and planned sensor applications and you get an idea of the potential. Simply put, the more electronics that a car uses, the more need for sensors to tell the computer what is going on.

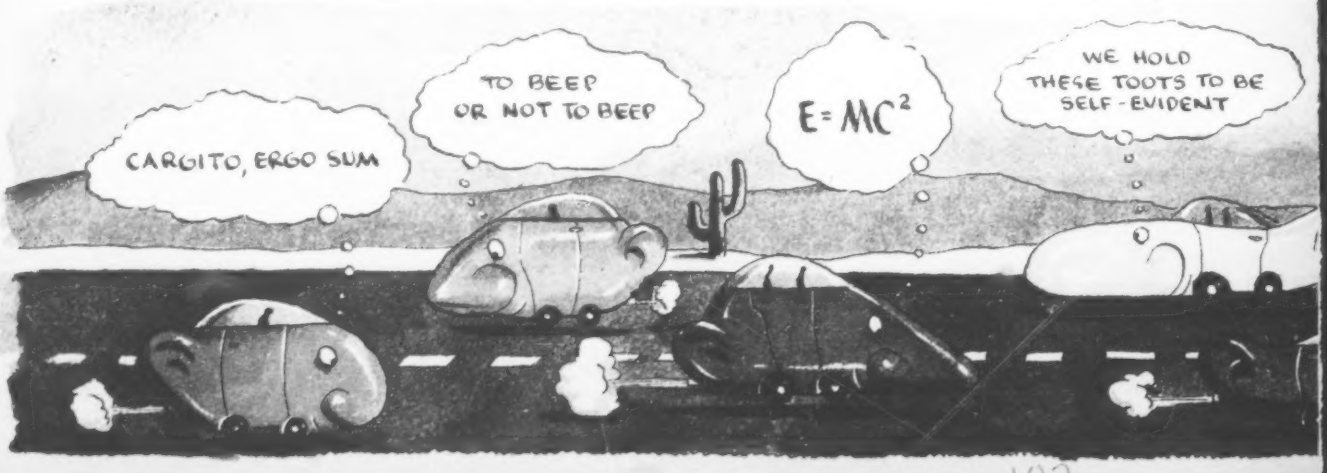
Automakers will buy almost $2 billion in engine and power train sensors this year

U.S. and foreign automakers will buy $1.97 billion worth of engine and power train sensors for the U.S. market this year, up from $1.81 billion last year, according to Venture Development Corp., a Natick, Mass., market research firm. Sales are expected to grow 6% annually for the next four years. Meanwhile, the real bonanza of sensor business in coming years will be for new, nonengine applications. Demand for other electronic and electromechanical sensors to make cars safer and easier to use will grow about 17% a year in the same period, from $727 million this year to $1.38 billion in 1992.

Largest sensor application

It's no wonder that suppliers are tripping over themselves to get or expand their pieces of the action. Production volumes are tremendous, according to Janusz Bryzek, chief executive and cofounder of Novasensor, a Milpitas, Calif., sensor start-up. Automobiles, he says, represent "the largest application for sensors today."

Major U.S. sensor makers include General Motors Corp.'s Delco Electronics Division, Honeywell Inc.'s Microswitch Division, United Technologies Corp. and dozens of smaller companies such as Novasensor. Japan's Hitachi Ltd. and Nippondenso and West Germany's Robert Bosch GmbH also are important players. While GM/Delco reportedly heads the list, there is no one dominant supplier. "There's a million different

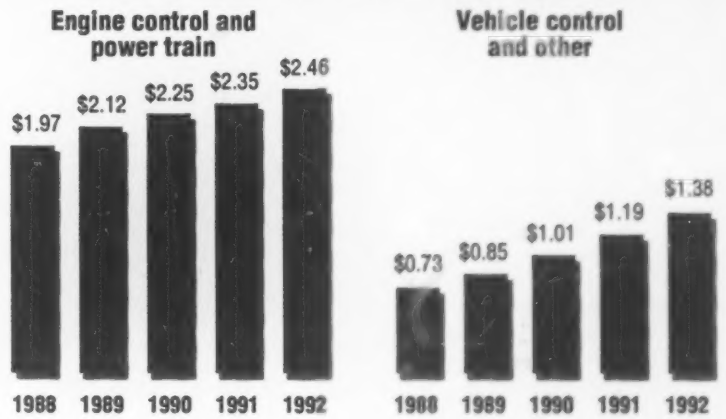


FOURTH IN A SERIES

As auto companies in the United States and Japan race to build the car of the future, sophisticated electronics technology is playing an increasingly important role. This story, the fourth in our series on automotive electronics, focuses on the expanding role of sensors in car design.

U.S. auto sensor market

Consumption of automotive sensors by manufacturers of passenger cars for the U.S. market ($ billions)



Source: Venture Development Corp.

technologies" used for auto sensors now, explains Joseph Giachino, supervisor for sensor development at Ford Motor Co., making it difficult for any single company to gain a monopoly.

In fact, the shift to new sensor technologies is what is providing many smaller sensor makers with an entree into the automobile market. Automakers are shifting from electromechanical sensors to more reliable, and in some cases less expensive, solid-state sensors and micro-machined sensors. Solid-state sensors rely on electrical changes induced in a material by such things as pressure, temperature and the position of a magnet. Micro-machined sensors, or silicon microstructures, are actually tiny electromechanical devices for measuring forces such as pressure, air flow and acceleration. Their parts are fabricated from silicon in a process similar to that in which integrated circuits are made. Currently, about 60% to 65% of all auto sensors today are electronic and the remainder electromechanical, according to Market Intelligence Research Co. of Palo Alto, Calif. But the shift to electronics continues.

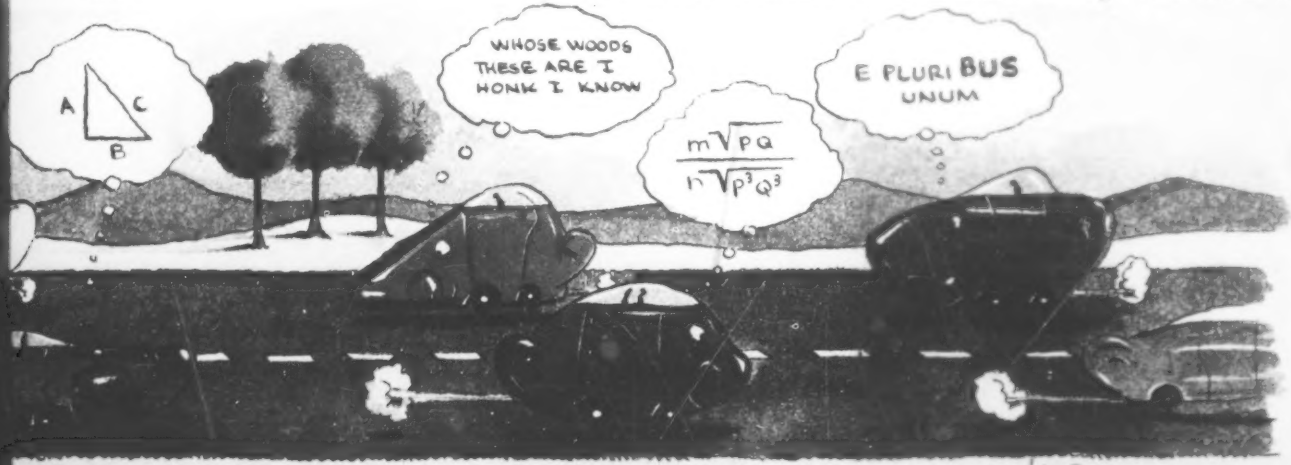
At the same time, large electronics systems makers are getting into the business in a big way by acquiring smaller sensor manufacturers. Allied-Signal Inc., Borg-Warner Corp. and TRW Inc., for example, have either acquired or forged working partnerships with one or more sensor makers to develop and supply sensors for their systems.

But despite the opportunities for sensor makers in new applications and new technologies, supplying the auto market today is a monumental task. All sensor designs for automobiles are custom, and sensor makers have to bear the cost of multiple redesigns, specification changes and whatever else is required to meet the needs of automakers. The first sensor applications were mandated and "you were driven to using what was available," says Ford's Giachino. Today's new applications, however, are refinements to the automobile. Sensor makers must meet carmakers' exacting specifications and no compromises will be accepted.

Some requirements have not changed. Sensors must operate in filthy, humid and sometimes salty environments, with torturous engine compartment temperatures spanning a range of -40 to +120°C. They must withstand constant vibration and shock. And the sensor maker must be able to supply them cheaply and in high volume.

Changing requirements

But some requirements have changed. Quality and reliability goals at U.S. automobile makers have skyrocketed in the past three years. Automakers are striving to produce cars that they can warranty for 10 years or 100,000 miles. "All of a sudden the [quality] norms from yesterday are gone," says Thomas Mabrey, director for marketing for Honeywell's Microswitch Division. U.S. automakers no longer want to take a

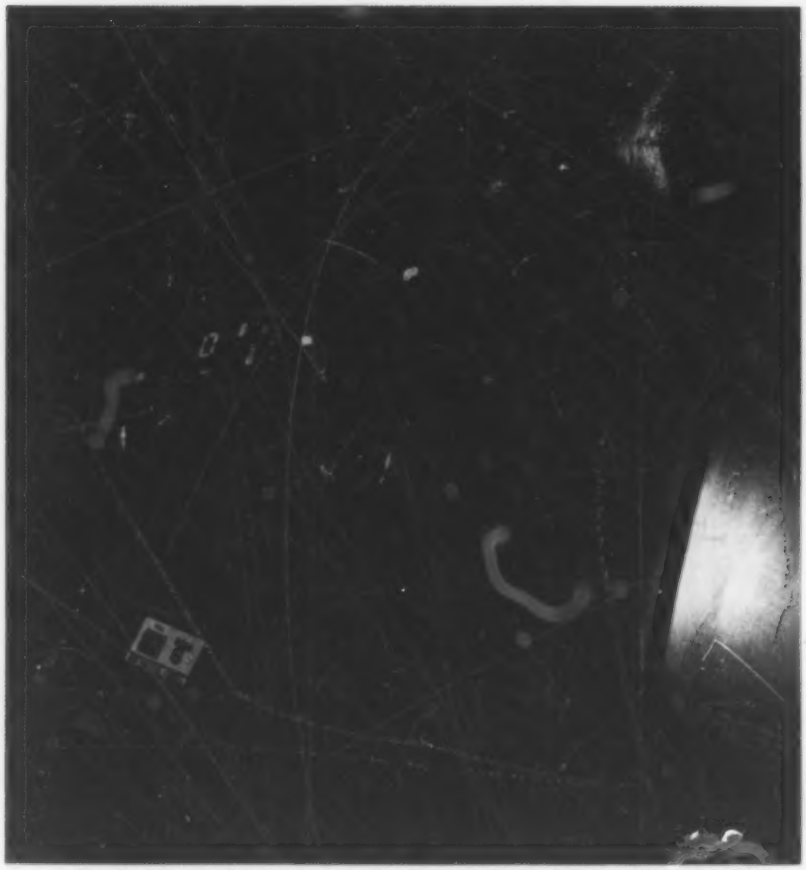


backseat to the Japanese with respect to quality.

Higher accuracy is also a new demand of automakers — particularly for new solid-state sensors used in engine control applications. Automakers want to provide tighter control of the engine, to provide better engine performance, higher fuel efficiency and lower pollution emissions. The reason? Engine performance and fuel efficiency are vital selling features of today's cars, and, experts say, auto companies are worried that the Environmental Protection Agency, which relaxed pollution control standards for the 1988 model year, will tighten them back up again.

But while these new and old requirements pose a considerable burden for sensor makers, perhaps the greatest burden they bear is enduring the arduous design-in process that automakers go through. While the design cycles of U.S. automobiles have actually gotten somewhat shorter than the five-year norm of several years ago, the effort has become more concentrated. Cars are subjected to more development work and testing than ever before. This has a direct impact on sensor vendors. "Everybody's relying on more and more up front development by the supplier," says Giachino.

Honeywell, for example, dedicates a full-time three-member engineering team to each custom project for its duration (typically three to five years). The team, based at Honeywell's Freeport, Ill., headquarters, is at the customer's beck and call. But even this commitment, says Honeywell's Mabrey, "is never enough in the eyes of the auto customer. Responsiveness is the real issue with them. They want to be able to call somebody and know they're going to get an answer when they need it."



Joseph Giachino, supervisor for sensor development at Ford Motor: "There's a million different technologies" used for auto sensors now, making it difficult for any single company to gain a monopoly

Massive development costs

And what do the automakers call about? They call about design changes. During a typical sensor design cycle, Honeywell will make four major design changes, which, says Mabrey, "is just like starting from scratch." In addition, perhaps six or more minor changes will be required, which may involve altering an electrical specification slightly.

Finally, once the design is approved and ready for production, Honeywell has about nine months to ramp up from zero to volumes of several thousand sensors per day. By this time, Honeywell has spent from $300,000 to $1 million on a major design. Although dedicated tooling and equipment is the customer's responsibility, says Mabrey, all other costs are born by the sensor maker. With this resource commitment required, there is plenty of evidence for the belief that supplying auto sensors has become a big company business. Says Ford's Giachino: "Small companies have gotten in in the past, but it will probably be harder to do in the future."

In fact, small sensor firms have allowed themselves to be acquired by larger companies to provide them with the economic wherewithal to sustain the necessary high development costs. Lon Bell, founder of 18-year-old Technar Inc. and now president of this TRW subsidiary, credits their acquisition with providing the resources to spur "triple digit growth" this year, with the same expected for next year.

But the acquisition of sensor makers is part of another trend: the move by automakers to purchase complete systems — such as an airbag system, a dynamic suspension system, or an antilock braking system — from a vendor. Such systems include a sensor as one small but vital part of a complete package of control electronics and system mechanics. Automakers like the idea of buying systems, because it shifts the responsibility for developing, testing and manufacturing major and complex chunks of the car to vendors. "It's a question of where can you put your resources the best," says Giachino. Contracting out allows automakers to become systems integrators and leave the more specialized work to specialists.

Junebug Clark

In 1986, TRW, for example, purchased Technar, which was previously a privately held, 150-employee manufacturer of crash sensors for the rapidly expanding crash bag market. Today, says Bell, 80% of Technar's sales are into complete crash bag systems or subsystems that TRW supplies to automakers.

For founder Bell, becoming acquired was an important strategic move. "It is my perception that it cannot be a long-range strategy to be just a components supplier," he says. The trend toward systems will continue, he explains, and those companies whose size is below a certain "critical mass" will be reduced to supplying the automobile market with components that are commodities, such as a bracket, an O-ring, or some mature, low-technology sensor.

Still, a small company can still make it today as a high-technology sensor supplier. For the small fish in this big pond, the key to survival is having a hot technology — and teaming up with a partner. For IC Sensors Inc., a maker of micro-machined silicon sensors in Milpitas, Calif., the move by the auto industry to buying systems is actually making it easier to supply the automotive market. In fact, IC Sensors' strategy is to sell to the systems houses, not to the automakers directly.

"We need the big buffer in between," explains Donald G. Lynham, president and CEO. The private, under $20 million firm takes advantage of the large systems companies' longstanding relationships with automakers, as well as their sales and marketing resources. "Small companies have a much more difficult time interfacing with the automotive people," says Lynham.

Although supplying the auto market via systems companies relieves the 6-year-old vendor of a considerable marketing burden, it still carries its own set of problems. For one, IC Sensors gives up much of the control and visibility over its market. If its customer, the systems maker, does a poor job of developing or marketing the system, it may never enter production, explains Lynham.

"You have to pick your customers very carefully or you can end up doing a lot of free work," he warns. Lynham looks for his customer's commitment to a particular project. "If he's putting his junior people on the program and saving all his good people for something else, it immediately raises a question mark.

Evolving auto sensor uses

Date of Introduction	Application
1978	Emissions contol
Early 1980s	Airbag trigger system
1984	Dynamic suspension system
1985	Antilock braking, compass
Early 1990s	Electronically controlled automatic transmission
1990s	Navigation control system, including radar and electronic maps

Risky proposition

Lynham tries to negotiate nonexclusive contracts that allow him to sell the sensor to multiple companies, although he acknowledges: "We don't always get our own way." He also negotiates for an up front supply contract guaranteeing that they will supply all or some portion of the production requirements for the application. But supplying system makers is still a risky proposition.

In the engine alone, 15 sensors measure everything from air flow to manifold pressure

Even though marketing is less of a problem in dealing with systems companies, the resources required are still considerable. Lynham estimates that a particular application consumes anywhere from two to six man-years of engineering talent, to get the project from the design stage to preproduction. The total bill often runs $500,000, with the sensor maker absorbing over half the costs.

The reason sensor vendors go through all of this, of course, is for the tremendous volumes that will be their's when (and if) a design reaches production. Revenue, however, is only one of the attractions. The automotive market has a far more strategic role for semiconductor sensor makers, not unlike the role that the dynamic random access memory market plays for traditional chip companies.

The ultra-high volumes of automotive applications act as a "technology driver" that pushes down sensor production costs across the board. "It makes you very competitive in all your other marketplaces," says Lynham. Also, he adds, being a supplier to the automotive industry enhances the vendor's credibility. "It's a very powerful sales tool for any other application you want to go after."

But Lynham is wary about allowing his company to become too dependent on the automotive market. Eventually, he wants to acheive a balance between IC Sensors' medical, industrial and automotive/transport businesses, relying on automotive for no more than one-third of his company's revenue. Today, automotive represents 10% to 15% of the company's business, with the majority split between medical and industrial.

Sensor makers view the automotive market as a building block for their companies, and IC Sensors' Lynham calls the considerable resources that they put into designs "an investment." At Novasensor, president Joe Mallon refers to his company's business strategy as a "two-phase plan." The first phase involves generating revenue by selling product into the medical and industrial sectors, which funds development work for the automotive product. The second phase comes when these automotive designs reach production.

What about the threat of the captive sensor divisions that many systems makers are acquiring? Doesn't this limit the independent sensor makers' market? Lynham says the key is to have advanced technology. If the sensor maker's technology results in the most reliable, low-cost solution for an automobile application, then it will make sense for a systems company to form an alliance with the independent company.

"The smaller companies have the technology," says Lynham, "and the bigger companies have the market opportunities, capital structure and horsepower." □

Wanted: Ways to beat the high cost of test

Firms that must test chips or boards are tired of spending so big to buy and use ATE gear. Here's what they — and the ATE vendors — are doing about it

BY DAVID CARD

Electronics companies have been whining about the high cost of automatic test equipment for years. Beyond the million-dollar price tags on chip and circuit-board testers, the cost of programming the machines often far surpasses the initial equipment price.

Al Key, a test manager at General Electric Co.'s Solid State Division, estimates that in most cases, test accounts for 7% to 10% of the manufacturing cost of a semiconductor device. The percentage of development cost is higher: 20% where CAE simulators produce many of the patterns used in the test program; but up to 70% where programs are extensively hand-tuned.

So now, many users are acting to beat high testing costs — in ways that could have a major impact on the already wobbly ATE business. Some companies are refusing to invest in the big-ticket testers, instead designing their products for easier testability and spreading lower-cost test systems along manufacturing lines. Others are turning to a technique called "scan" technology, which considerably enhances testability of more complex systems. And top management at many ATE users, which has always signed off million-dollar purchase orders, is now becoming involved earlier in test strategy sessions.

Apple's VLSI test manager, James Bray: "The answer long-term is the complete integration with simulation"

Cindy Charles

Anticipating the market shifts ahead, the ATE suppliers are also coming up with cost-beating solutions. Some already offer low-cost models; others are pitching stripped-down models aimed at particular test niches. And most are making their testers easier to program, and tying them closer to computer-aided engineering. But the vendors argue, as do most ATE industry analysts, that is about as much as they can do — quality products demand quality testing, and quality testers don't come cheap.

Users can also make test savings a matter of resource management, according to Joseph Lassiter, vice president of ATE leader Teradyne Inc. He suggests that management must stop rewarding design engineers based on time-to-prototype. Instead, an approach that values time-to-shippable product is needed. That way, testability would receive the attention it deserves, he says.

There are other options, of course: "The classic way to keep test costs down is to get your vendors to test for you," laughs Edwin Ely, director of U.S. systems and hardware engineering at Siemens Information Systems Inc. in Boca Raton, Fla. Realistically, Siemens tries to push testing back as early in the manufacturing process as possible. A project's test director, working with engineering and design personnel, decides how this is done, then Ely reviews the process.

New buyer profile

The users' new buyer profile is evident to Vincent Lutheran, general manager of Tektronix Inc.'s Semiconductor Test operation. He says that when trying to sell his new model, he runs into division managers at least, and usually vice presidents. He often brings along Tek divi-

sion vice president Richard Knight and even president David Friedley. Tektronix may be a $1.4 billion company, but considering all the businesses Tek has recently spun off, Lutheran has to convince potential customers that Tek is in ATE to stay. It is unlikely that ATE leader Teradyne's president Alexander d'Arbeloff has to make similar reassurances.

Tektronix offers examples of the new wave of relatively low-cost test practices. Tek's Vista family of testers is aimed specifically at custom chips, and weighs in at $500,000 to $1.9 million, rather than starting at a million and a half. It's an open secret that Tek is also exploring the latest ATE niche — the so-called design verification systems. Verifiers are another peg lower in cost, and are geared to test prototypes and short runs of custom chips.

Plus, Tek's Knight says his company is looking seriously at the board test market for the first time. Integrated circuits, he says, will always require a big tester at the end of the line, but board testing is different. "Board test has historically grown up around super machines," Knight says, "but the manufacturing environment is changing." Techniques such as just-in-time inventory schemes and manufacturing cells demand "smaller, more flexible machines distributed throughout manufacturing."

Support Technologies Inc., a Tek neighbor in Portland, Ore., makes such a tester. Support originally targeted the service test industry, but now finds half its business in production and manufacturing. "A major price restructuring is going to happen" in the board test business, remarks Support vice president Thomas Bush. Of course, this comes from a company that expects to see $6 million in sales this year. Cynics point out that nothing really happens in a new market until major suppliers come in. No one believed in in-circuit board testers until big guys like GenRad Inc. and Hewlett-Packard Co. started selling them, according to one market researcher.

Exorbitant costs

San Jose-based industry watcher VLSI Research Inc. shows that the average selling price of a high-end component tester topped $1.2 million last year. Ten years ago, an aeon in electronics, testers cost under $400,000. "The reason people spend these exorbitant prices is that these testers are the best way to get the job done," analyst Dan Hutcheson says. "There is not some magical company out there that has figured a way to test cheaply."

The cost of developing these testers is as exorbitant as their price tags. Hutcheson estimates a company has to spend $50 million to $100 million to get into the ATE business. So eight or nine suppliers are spending $1 billion every five years for a market that's worth "maybe half a billion dollars," he says. Making money in such a market is hardly the easiest thing in the world.

The ASP of a high-end component tester topped $1.2 million last year, three times its price 10 years ago

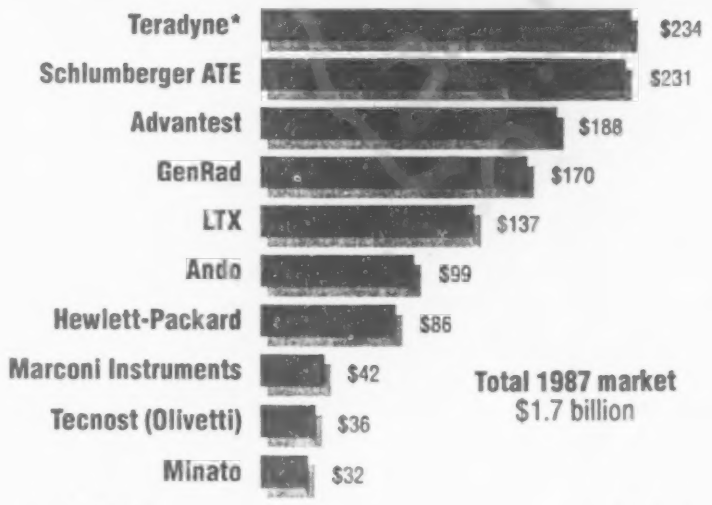
Megatest Corp. president Steve Bisset is almost nostalgic for the days when Fairchild Camera and Instrument (now Schlumberger ATE) dominated the ATE market. Smaller companies picked niches "and we made lots of profit," he says. Now, many semiconductor companies expect to try out ATE for six months — for free. Bisset says that's asking Megatest "to commit suicide." Trillium president James Healy blames that practice on Japanese ATE companies, whose rich parents (Fujitsu Ltd. for Advantest Corp., NEC Corp. for Ando Corp.) can afford it. It is like giving a little kid a puppy, Healy says. "And who's going to give back the puppy dog?"

Trillium did just introduce a $350,000 model indicative of the latest ATE strategy — offering cutdown models for simpler production testing. "I don't think we could go any lower," says LTX Corp. vice president Roger Blethen. Westwood, Massachusetts-based LTX is Trillium's parent.

Semiconductor Test Solutions Inc. pioneered the market Tektronix's testers are entering, because president David Mees saw multimillion-dollar testers and could not "imagine a production line with 10 or 20 of those." STS testers, for instance, coexist with a Megatest model and verifiers from Asix Systems Corp. and Integrated Measurement Systems

Top suppliers of ATE in 1987

Worldwide sales ($ millions)

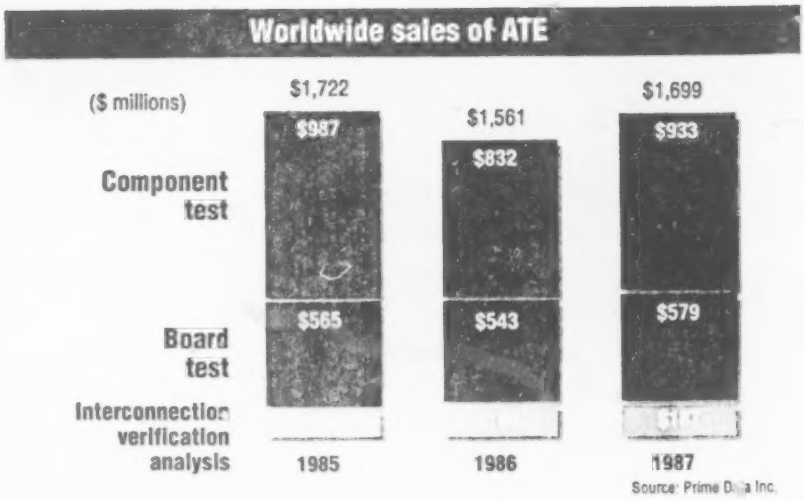


* Includes Zehntel

Source: Prime Data Inc.

Corp. in VLSI Technology Inc.'s production room, labs and design centers, according to VLSI's test manager, Kenneth Von Egmond. Yet Mees, who makes testers priced in the midrange, is feeling enough heat from below to consider reselling —or buying a maker of — verification systems "as a barrier."

It's not as if the verification market is not feeling ripples itself. San Jose market research firm Prime Data Inc. says the business was worth just under $40 million last year and sales growth is slowing down. "It is already crowded at the low end," says Hewlett-Packard marketing exec Matthias Stahl, whose Boeblingen, West Germany, division is introducing a new verifier this month.



Scanning the horizon of test

Still, industry watchers agree that the move to cheaper systems is faster in board test. Board test leader GenRad is well-positioned to take advantage of market shifts — its Phoenix division makes low-end testers that compete with those from Support Technologies. GenRad president Robert Anderson admits that computer companies, which tend to buy his low- and midrange products, are less likely to buy his top-line models. "There's no question that doing a good job of design verification and process qualification reduces the number of testers needed," Anderson explains.

Meanwhile, ATE consumers are still concerned about cost. "Boundary-scan will beat the high cost of test," says Sol Black, senior engineer at AT&T's Circuit Pack Test unit in Columbus, Ohio. Scan technology is a process where paths are designed into circuits giving a "window" into their functions. Extra switches are added to the design to "serialize" the complex logic functions of a circuit, and to make them more easily traceable by test equipment. Scan does impose performance and chip real estate penalties, but Black and others say it is getting to the point where boards and chips will become too complex to test without it.

Black tests boards with a variety of in-circuit testers, but he is not particularly fond of the situation. For one thing, his testers have to attach to the board by probes connected to each component. As less accessible surface-mounted components populate AT&T boards more and more, the connection problem becomes "scary," according to Black. Scan-designed chips on a scan-designed board would allow Black to use "a lot less expensive testers." But few

ATE market outlook: Boom in '88. Bust in '89?

Relatively speaking, 1988 will finish a boom year for ATE. So why aren't suppliers smiling? Robert Anderson, president of board test leader GenRad Inc., says he doesn't want to use the "B" word "because it implies 'bust' follows it. We're being very careful how we ramp up." Anderson says GenRad had its best first quarter in over three years — and that was after getting out of the chip test business. GenRad did, however, have a flat second quarter.

Analyst Kenneth Neff at Prime Data Inc. forecasts a 13% to 15% growth in world ATE sales for 1988. Sales will nudge $2 billion this year, but plod up only 5% in 1989, when Neff is calling for a general economic slowdown. After that, things should bounce back to "middle to high teens" annual percentage growth.

Recession next year? Anderson says: "Can't call it yet. Who knows?

Worldwide ATE sales will nudge $2 billion this year, but plod up by only 5% in 1989

Typically, board test lags chip test. That correlation was a little out of whack from 1985 through 1987, but if it's true, that should translate to steady demands later this year and early next year."

Frederick Bihler, president of Japanese chip tester Advantest Corp.'s U.S. subsidiary, is pretty chipper: "We're generally forecasting an improvement over last year, which was a record year for us." Irwin Pfister, vice president of Schlumberger ATE, is seeing improvement across all product lines for a change. That means board test sales are up, too. Still, it's "not a runaway market."

Edward Rogas, a vice president at Teradyne Inc., agrees that "business across the board — some is very good and some is good." Rogas says he doesn't think that anyone is "massively buying," but memory test sales are booming —at least to manufacturers in South Korea. □

merchant chip makers use scan.

Logical Solutions Technology Inc. of Campbell, Calif., is trying to change that. President Jon Turino is pushing a scan-oriented "testability bus" design through IEEE standards committees later this year. Logical Solutions will gladly sell you a chip set incorporating the bus, or license the technology to merchant semiconductor houses. A 50-cent testability chip will allow boards to be tested by $150,000 testers instead of $1.5 million ones, Turino claims.

Apollo Computer Inc. used a scan-oriented simulator from Teradyne's Aida division as well as others to help design the RISC processor at the heart of its latest workstation. Apollo management had to buy into the theory of design for testability early on, says marketing manager Paul Bemis. For one thing, Apollo had to do some serious simulation — 25 of its high-end workstations, 17 with Aida accelerator boards, were dedicated to simulation. Apollo spent a whole year doing timing verification after the initial design was done. And it gambled on a small company for its chip, Integrated CMOS Systems Inc., partly because of its scan expertise.

Sunnyvale-based ICS tests Apollo's chips with a special scan tester from start-up Gillytron Inc. of San Jose. Gillytron's ultra low-cost, personal computer-based tester can test the ICS chips more thoroughly than conventional ATE, claims ICS vice president Tom Miller.

Here are a few other examples of users' strategies for beating the high cost of test:

AMD: Pay up front

Advanced Micro Devices Inc. vice president Gary Ashcraft admits that his strategy to trim test costs — buying big, costly testers early — appears contrary. "It probably isn't obvious from casual observation," says the head of AMD's Austin, Texas, Communication Products Division, "because they *are* very expensive testers." He's talking about his top-of-the-line, million-dollar, mixed-signal A500 tester from Teradyne.

But Ashcraft says the ploy saves in the long term. The A500 allows him to test the analog and digital functions of AMD chips simultaneously. With test times measured in seconds, loading a chip into two separate testers costs money in terms of "throughput." The A500 is easier to program, he says, so that even with the mixed-signal capability, a single engineer can handle a given component. Ashcraft is seeing up to 50% productivity gains in his programmers. Productivity is key, he says: "Even if the testing costs the same, it's worth it in terms of time-to-market."

Apple: Software salvation

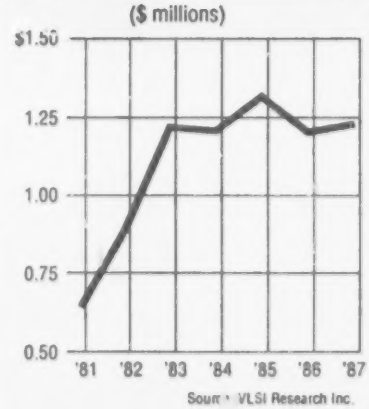
How to beat the high cost of test? "The answer long-term is the complete integration with simulation — where the tester software *is* the simulator software," responds Apple Computer Inc.'s VLSI test manager, James Bray. He wants to eliminate test programming completely.

Apple simulates ASICs with Mentor Graphics software, but Bray is also investigating "next generation" tools from Gateway Design Automation Corp. as well as HHB System's automatic test program generator. Apple's simulation mandated a per-pin tester for easy programming, and Bray is evaluating machines from LTX/Trillium, Megatest and Teradyne.

Apple's automated Fremont, Calif., plant is geared to just-in-time manufacturing. So Bray actually doesn't do much incoming inspection: "We want to push that back on the vendor." He won't force an ASIC house to use the same kind of tester he uses, but doing so is the only way to use Apple's design data efficiently.

Two separate project teams at Apple are evaluating various scan techniques. Bray says Apple is so sold on scan that if chip vendors don't adopt it, Apple might put in its own. For instance, rather than buying standard 68030 microprocessors from Motorola Inc., Bray speculates, Apple might license the 030 technology, and build up scan and other functions around it in a custom chip.

Average selling price of a VLSI chip tester



Barring price-pressure dips during two economic downturns, tester price tags are headed unerringly north

Honeywell Military Avionics: Small is beautiful

They test testers at Honeywell Inc.'s Military Avionics Division, and they like to use small, low-end equipment to do it. Production engineering supervisor Jon Thom's group builds and tests some of the boards that go into the Air Force's MATE military tester.

A Honeywell team was looking at functional testers — the million-dollar kind from GenRad and Teradyne — but realized that the benefits from those were largely simulator-driven. Since the MATE design team didn't use simulation, Thom reasoned, he didn't want to spend that much.

So Honeywell opted for a low-end functional tester from Support Technologies that plugs into the MATE system's controlling microprocessor. Honeywell also practices distributed testing: before a MATE board reaches functional test, an in-circuit tester from GenRad catches manufacturing defects.

Honeywell design engineers don't simulate the MATE boards, but they do write diagnostic procedures — the Air Force requires it. Those procedures translated to the Support tester, Thom says. To ensure design/test cooperation, Honeywell "transferred some design folks into production." The strategy was easy to sell to management because it "saved a lot of dollars and a lot of the schedule." □

PCB firms spending more in face of coming shakeout

As quality becomes customers' No. 1 priority, board makers are investing heavily in automation and optical test equipment

BY TONY GREENE

Quality is the name of the game in printed circuit boards these days. When industry executives are asked what their biggest challenge — and No. 1 priority — is, the answer is unanimous: quality. Customers are getting tough. Where once fail rates were measured in parts per hundred or thousand, customers now are demanding PCB manufacturers deliver goods that have a fail rate of parts per million.

Meanwhile, as PCBs get more sophisticated, it gets harder to meet customers' demands for vastly improved quality. Today, buyers want finer lines, more layers and new technologies, such as surface mount. The increasing prevalence of just-in-time manufacturing, which mandates the delivery of near-perfect goods to the OEM just in time for use, also is driving the push for quality. To meet all these demands and still provide better products, companies must invest heavily in new equipment.

Indeed, quality costs money — and lots of it. To satisfy demanding customers' requirements, PCB manufacturers must invest in advanced technology, including costly electrical and automated optical (AOI) inspection.

Unfortunately for PCB makers, the investment funds must be raised in an industry that most analysts agree has one of the lowest average profit margins, around 10%, in electronics. From now on, it's survival of the fittest. And the survivors will be those with money to spend. So, while quality may be the buzzword on everyone's lips, money for capital expenditures — and where it will come from —is the problem on everyone's mind.

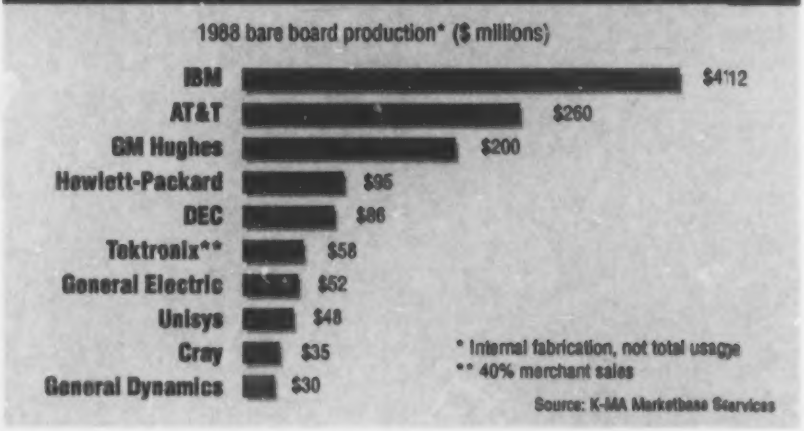
Most PCB analysts agree that there will be a shakeout, consolidating the industry at the top end. The big shops, with more than $50 million in sales a year, will get bigger. And the medium-sized shops — $10 million to $50 million annually — will get squeezed out. With less need for expensive automation equipment for prototype work, the number of small shops, with annual revenue of $10 million or less, should remain relatively constant. Still, things could get tough as the large shops become proficient at quick turns on small orders. The PCB industry in the United States is estimated at $5.4 billion for 1988, with a growth rate of 16.9% for the year, says Philip Lapin, president of Electronic Marketing Consulting, Redwood City, Calif.

While capital investment strategies vary, PCB makers actually have several things in common. They are:

- Buying equipment that will increase production yields and speeds. Big board makers are leaving the cutting edge technology to small shops, concentrating instead on automation.
- Diversifying product lines and customer bases to avoid depending too much on any one customer, as many did before the 1985-86 slump.
- Concentrating expenditures on equipment that will insure good-quality high yields. As production output has risen, it has become imperative that flaws are caught quickly and corrected immediately. "Automated optical inspection is near the top of the list," says Harvey S. Miller, president of K-MA Marketbase Service, a Palo Alto, California-based research firm.
- Borrowing little and financing capital investments internally. Many PCB makers are still saddled with debt incurred before the slump and they don't want to get caught short again.

"We try to put 10% of revenues toward capital expenditures," says John Kropper, president of Hadco Corp., Salem, N.H. "And we try to finance our capital investment out of earnings." Kropper says that Hadco has already spent $8 million in the first six months of 1988 and that he expects to spend another $8 million in the second half. ▷

Top U.S. captive makers of printed circuit boards



Hadco led the industry last year with sales of $115 million and expects to lead the industry again this year with sales of $140 million, a 22% increase. Hadco's investment strategy also includes a plan in which sales and marketing employees specify the kind of products that they believe customers will want over that period, and recommend the kind of investments that will be needed to fulfill that demand. The manufacturing team then comes back with plans to satisfy those requests.

John Carr, president of Continental Circuits Corp., a Phoenix, Arizona-based PCB manufacturer, agrees. "The key to our capital investment strategy is to plow revenues right back into the business," he says. Continental Circuits generates about $1 million in cash every month, according to Carr, with profit margins averaging 11.5% of sales. The firm predicts sales will climb 25% this year to $75 million, from $60 million in 1987. Carr, meanwhile, expects to spend $10 million this year and $20 million more in the next two years on capital equipment. Continental tried to raise some of that money through an initial public offering in October of 1987, but got caught in the stock market crash and had to abort the plan. Continental also subsidizes its purchases by selling the equipment that is about to be replaced. The company has a full-time employee who does nothing but find buyers for the used machinery.

Fifth-ranked Advance Circuits Inc. of Minnetonka, Minn., has a different strategy. "We try to limit our capital investment so that the amount that we spend is equal to our depreciation," notes Thomas Leahy, Advance Circuits chief executive. "We want to pay our debts with depreciation." In 1980 and 1984, Advance Circuits defrayed costs by raising funds through stock offerings — an advantage, Leahy says, that public companies have over private firms. Advance Circuits has invested $15 million in equipment in the past three years.

Top U.S. independent makers of printed circuit boards

Source: K-MA Marketbase Services

Independents gain ground

These strategies seem to be working. Independent PCB makers are increasing their share of the total market. In 1987, independents captured 60% of the market, with captives accounting for the remaining 40%, according to the Institute of Interconnecting and Packaging Electronic Circuits (IPC), in Lincolnwood, Ill. For the independents, that's a 9% increase from the previous year.

The big captive operations still dwarf the largest of the independents, However. IBM, the U.S. leader in PCB manufacturing, is forecast to build $412 million worth of boards in 1988, while AT&T and GM Hughes Electronics Corp. are expected to do $260 million and $200 million, respectively. One reason these shops are going outside with board business is that independent board shops are performing better than ever.

The big PCB firms will get bigger and the medium shops will get squeezed out

"Captive operations are using the independent manufacturers as a buffer for their business operations," according to Gene Hendrikson, general manager of Tektronix's PCB facility. "We would rather handle the increase in the independent market than spend the money on the equipment ourselves." Tektronix has made a move toward the independent market, doing 40% of its projected 1988 sales of $58 million in the merchant board market. According to Hendrikson, Tektronix is performing well enough in the independent market to fund its own operation. "We have reached the point where we can compare with the best independents in the business on cost and quality," he says.

"Printed circuit boards are the kind of product that work best in an independent environment with an entrepreneurial approach," says K-MA Marketbase's Miller. Because of this flexibility, independent board makers can produce higher quality products for less than captive shops. Jack Mettler, president of North Haven, Connecticut-based Circuit Wise Inc., notes that the IPC figures also reflect increased demand for printed circuit boards this year and last. There are other factors driving OEMs with captive shops to the independents. "The market as a whole is going to independents because of specialization," says Continental Circuits' Carr. "Historically, large companies go outside to fill increased demand during upturns," observes Mettler.

As the industry consolidates, customer service is becoming increasingly important. "There is more and more inclination for the customer to go with one supplier," says Ray Pritchard, IPC's executive director. Miller agrees: "The trend is toward maybe five vendors instead of 200." The No. 1 reason for this is the demand for quality.

As boards become denser and more complex, customers are looking for manufacturers that can provide consistent product and deliver it on time. These same factors are responsible for the fact that PCBs are not im-

ported or exported in great numbers. Multilayer, for example, "is such a complicated product that you need to have the manufacturer and the customer on the same continent," says Miller.

Independent board makers are developing strategies to be more responsive to customers. "One of the ways we are servicing our customers is by having resident engineers that work for us live in the customer's factory," says Keith Robbins, vice president of fourth-ranked Photocircuits Corp., Glen Cove, N.Y. "That way, the minute the guys at the factory know about a problem, our guy there knows about it. And he can call us and tell us how to get it fixed."

Customer service

Hadco, meanwhile, practices what it calls multiple tier selling. "We talk to the executives, the engineers and the support staffs to find out what everybody needs," says Andrew E. Lietz, sales vice president. "We want to support leadership and innovation and form partnerships with long-term technical visions."

Customer service is only going to become more difficult, and the need for capital expenditure is going to rise as the technology involved in the manufacturing of PCBs becomes more and more complex. One of the major forces in this push is surface mount technology. SMT is driving the size of linewidths down, and is causing the density of the boards to increase dramatically as chips are being mounted on both sides of multilayer boards.

"The increasing density of boards is running the prices up faster then customers want to pay," says Prudential Bache analyst Edward B. Keaney. Pritchard at IPC says, "It is difficult for companies to charge a reasonable amount for their product." In addition, increasing use of JIT in manufacturing is pushing up demand for perfect production runs at low prices. "Anybody who is not looking at just-in-time is not going to be in the business in the next five years," according to Pritchard.

Printed circuit board makers also are working hard to diversify and expand their customer bases. None of the manufacturers want to be so closely ties to one customer that their fates are inextricably intertwined. "No one customer is allowed to represent more then 15% of our business," says Hadco's Kropper.

In line with this is a push by the large manufacturers to diversify product lines and not become tied to one group of OEMs. Finally, the doctrine that is sweeping the industry is high tech at high volume. It is not as important to be on the cutting edge as it is to produce the high-tech boards — and a lot of them. As a result, the big board shops are happy to leave the small specialized orders to the prototype shops. ▷

Orange peel to the rescue

Scientists have been saying for years that the ozone layer, a critical portion of the earth's upper atmosphere, is disappearing at an alarming rate. All this concern is because the ozone filters out ultraviolet radiation from the sun before it reaches the earth, allowing us to enjoy the sun without undue fear of skin cancer and other complications that unfiltered sunlight can cause. But the ozone is under chemical attack from chlorinated fluorocarbons, which are used in spray cans — and in circuit board manufacturing.

Orange peels may save the day. AT&T and Petroferm Inc., a small chemical company, have together developed a compound they say will replace Chlorofluorocarbon-113 (CFC-113) as a solvent in the electronics industry. The compound, Bioact EC-7, is a natural solvent derived from orange and other citrus rinds, as well as wood products. The Enviromental Protection Agency estimates that 10% of the ozone-depleting compounds could be eradicated by using Bioact EC-7 instead of chlorofluorocarbons and other chlorinated solvents.

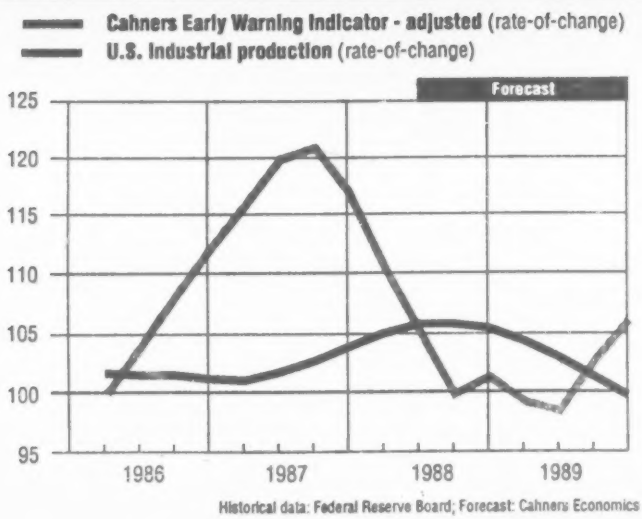
Petroferm's Michael Hayes: It's so safe that in some cases it's called an indirect food additive

"The compound is so safe that it is on the government's Generally Regarded As Safe (GRAS) list and in some instances is even listed as an indirect food additive," according to Dr. Michael Hayes, the compound's inventor. Bioact EC-7 is based on terpene hydrocarbons, which are compounds that occur naturally in almost all organic substances such as: citrus fruit rinds, vegetables, spices, meats and wood products. Terpenes are already being used in household solvents like Pine-Sol and Lysol.

"In addition to being environmentally safer than CFC-113, Bioact can outperform it," says Hayes, referring to a test he has conducted comparing the two compounds' abilities to remove flux, or residue, from printed circuit boards. However, one problem with Bioact is that it must be used only on products that can be immersed in water and in cleaning systems that can accomodate a water wash. Hayes says that Vitronics Corp., a PCB equipment manufacturer, is developing equipment to take full advantage of the compound.

According to John Fisher, supervisor of the solder process technology group at AT&T's Engineering Research Center in Princeton, N.J., "Another benefit of Bioact is that you need less of it. It has a high boiling point and a high loading capacity. It can dissolve a lot of resin and still clean efficiently. The people who are using it are very happy with it." □

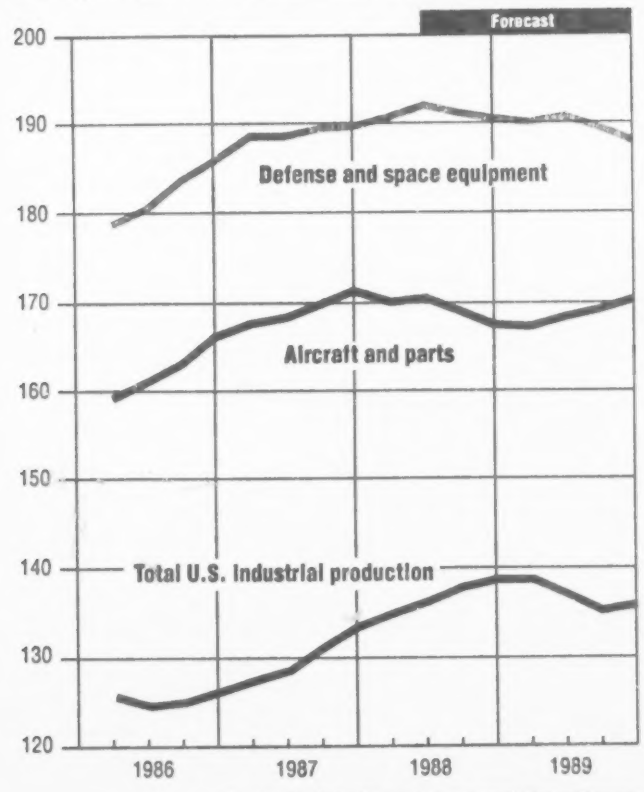
U.S. economic indicators



Historical data: Federal Reserve Board; Forecast: Cahners Economics

Defense equipment — Industrial production

Quarterly averages, 1977 = 100, seasonally adjusted



Historical data: Federal Reserve Board; Forecast: Cahners Economics

U.S. production growth remains steady

The indicator peaked in the third quarter of 1987 and is heading for a low point in the second quarter of 1989. But the downturn will be mild and short-lived, according the CEWI readings. The growth expected in U.S. industrial production has been revised downward slightly for 1988 by Cahners Economics. So, instead of slowly accelerating growth this year, industrial output will hover around the 5.1% to 5.9% range all year, before heading down in 1989. The reason for the revision? Inventories of imported goods are high. This could result in greater import price competition and U.S. manufacturers could feel the heat. Still, export growth and renewed business investment will steer U.S. industry to steady growth gains this year.

More information can be obtained from Elizabeth Baatz, economist, Cahners Economics Department, 275 Washington St., Newton, Mass. 02158.

Electronics on top in defense market

Something happened this past April and May that hasn't happened since July of 1978. U.S. factory output of defense and space production fell below year-ago production levels. This decline is indicative of the future state of the defense industry. Cuts, delays and stretch-outs are the depressing future vocabulary of the industry.

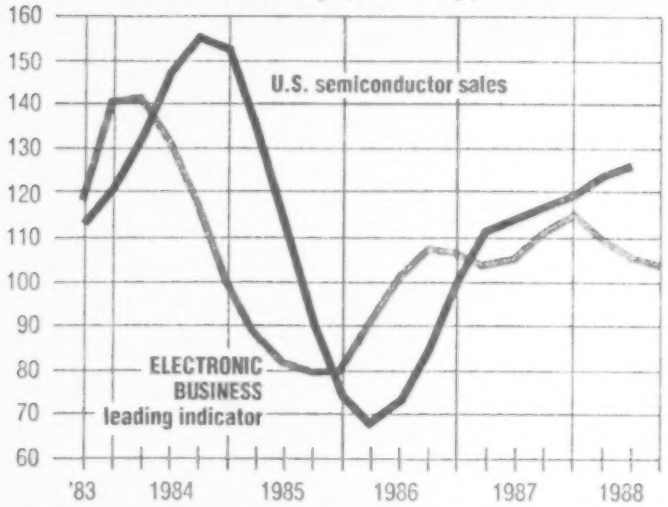
Although the defense budget will be cut (regardless of who's in office), the defense electronics industry cuts won't be as deep. The pressure to modernize, even though awards for new high-tech systems will be rare, will mean existing systems will be upgraded with new electronic equipment.

According to estimates by the Electronic Industries Association, the total Department of Defense budget will decline 3.2% per year on average over the next 10 years. Meanwhile, the electronics portion of that budget will see a 2.6% average annual increase over the same period.

In fiscal year 1987, about 18% of all defense contracts greater than $25,000 were spent on electronics and communication equipment. Another 22% were awarded for aircraft and related equipment and 16% for missiles and space equipment. Over the next decade, electronics' slice of the shrinking defense pie is bound to get bigger.

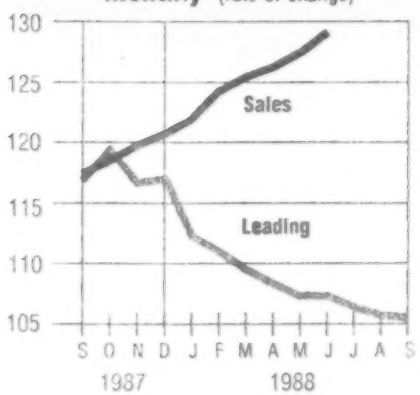
ELECTRONIC BUSINESS leading indicator

Quarterly (rate-of-change)



The ELECTRONIC BUSINESS leading indicator predicts turning points in U.S. semiconductor sales with about a three- to nine-month leadtime. For more information please contact Elizabeth Baatz, senior economist, Cahners Publishing Co., 275 Washington St., Newton, Mass., 02158, or call (617) 558-4368

Monthly (rate-of-change)



The ELECTRONIC BUSINESS leading indicator saw a decline for the fifth consecutive month in May and is expected to continue declining over the next few months. A drop in stock prices and semiconductor bookings contributed most to the early 1988 slowdown.

Source: Cahners Economics

Electronics industry indicators this month

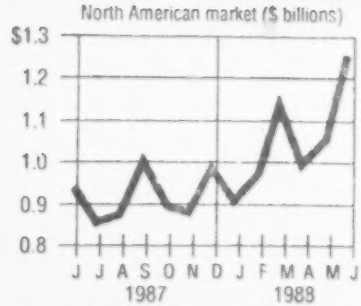
	Latest month	Previous month	Year ago	1987 average
ELECTRONIC BUSINESS leading indicator (rate-of-change, May)	108.3	109.5	107.4	111.8
U.S. semiconductor bookings ($ millions, 3-month average, June)	$1,269	$1,223	$981	$951
Weekly hours of semiconductor production workers (monthly average, May)	40.1	40.1	40.6	40.6
Electronic components leadtime index (1977 = 100, July)	123.2	120.2	120.5	100.7
S&P's semiconductor stock price index (1970 =10, monthly average, June)	64.6	58.2	68.0	65.5
Change in electronic components inventories ($ millions, SA, May)	-$50	+$25	-$809	+$47
Contract and orders for plant and equipment ($ billions, SA, May)	$35.8	$37.6	$34.6	$34.5

SA = seasonally adjusted, all other data is not seasonally adjusted

Sources: Semiconductor Industry Association, U.S. Bureau of Labor Statistics, *Electronics Purchasing* magazine, Standard & Poor's, U.S. Commerce Department, U.S. Bureau of Economic Analysis

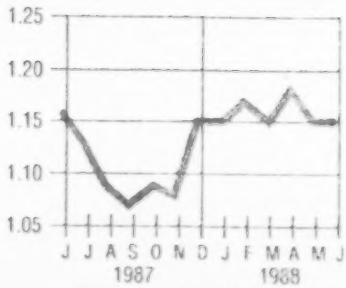
Semiconductor sales

North American market ($ billions)



Source: Semiconductor Industry Association

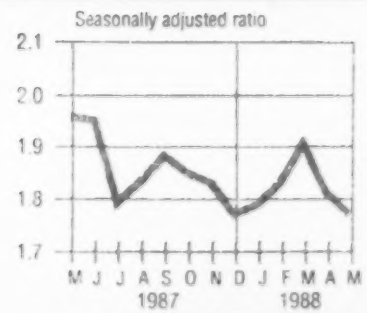
Semiconductor book-to-bill ratio



Source: Semiconductor Industry Association

Component inventory-to-shipments

Seasonally adjusted ratio



Source: U.S. Commerce Department